WITH SUPPLEMENT---LAVOISIER'S ANALYSIS OF AIR AND WATER

Vol. I.] FEBRUARY, 1902. [No. 9.

School Science

A Journal of Science Teaching in Secondary Schools.

EDITED BY C. E. LINEBARGER.

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SCHOOL SCIENCE, Room 1318—138 Washington St., CHICAGO.

Published Monthly, September to May Inclusive.

Price $2.00 Per Year. 25c. Per Copy.

Entered at the Post Office in Chicago, Ill., as Second-Class Matter.

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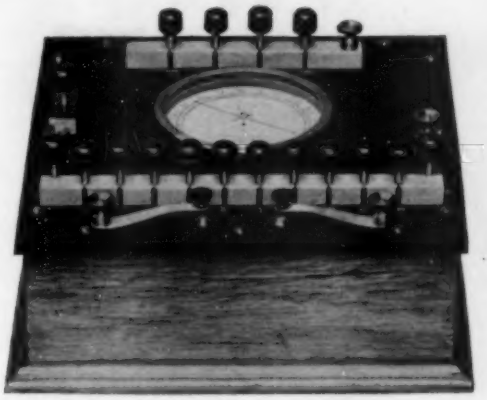

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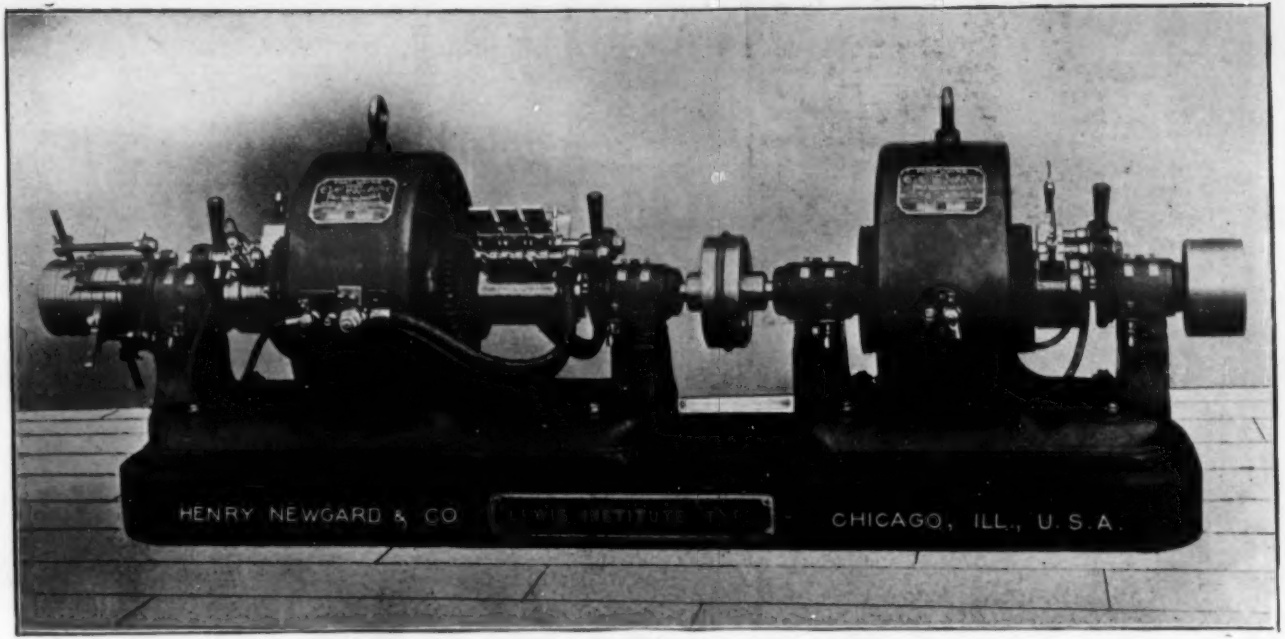

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School Science

VOL. I] FEBRUARY, 1902. [NO. 9

CLASSIFICATION AS AN ELEMENT OF EDUCATION.*

BY N. A. HARVEY,

Head Critic of Chicago Normal School.

I assume as the basis for this discussion, that the teaching considered in this paper is educational in its nature rather than professional. I mean by this that it shall be for the ultimate purpose of training the mind to do better what all minds can do in some degree, rather than to accumulate a fund of information to be used in the practice of a profession. The psychological movement of the learner rather than the logical development of the subject is the thing that is of the first importance, and is the chief factor in determining the method to be employed.

Permit me also to state that in all my illustrations I shall have in mind the teaching of science in high schools. If the teaching of scientific subjects in colleges and professional schools were to be considered, the illustrations and basic propositions would need very considerable modification.

The greatest contribution of science to education is the scientific method. The scientific method is not a method of teaching, but it is a method of thought, and is capable of universal application. It is called the scientific method because it has been developed chiefly in scientific subjects by scientific men. Its importance is so great and so fully recognized that we are continually finding the scientific method applied to subjects formerly considered most remote from scientific facts.

*Part of a Paper on "The Study of Types, Its Significance and Its Application," read before the New York State Science Teachers' Association, December, 27, 1901.

In the scientific method of study, an individual is the first thing to be considered. From this fact the scientific method is sometimes regarded as an example of induction. In reality, the scientific method is quite as much deductive as it is inductive, but the starting point is the same as in a case of pure induction. This individual which is taken as the starting point may be called a type, since it always embodies the characteristics of the group that is founded upon it. A type may, however, mean much more than the individual that is studied. It necessarily involves all the characters that enter into the concept of the class, but it should be one that contains the average characters of the class. Individuals of the same kind are not all alike. Variations occur that make them individuals. These variations are quantitative in their nature, and in some individuals are much greater than they are in others. In any group of individuals that are combined into a class, there will always be extremes of variation, and an average point or norm, from which variations occur. In the vicinity of this norm will be found the greater number of individuals that constitute the class. It is this average, this point of departure, this possessor of common characters in the least variable degree that may stand for the type of the class. It will be seen, then, that the selection of an individual to stand as the type of a group is a matter demanding considerable care. It certainly would be very unwise to select as the type for study one of the most aberrant or divergent forms in the group.

It is evident that the selection of an individual to stand as a type will depend upon what it typifies. An individual is not a type unless it stands in the mind for a class, or stands as the representative of a group, all of which have common characteristics. We come at once, then, to classification as an element in scientific study. Classification is implied in almost every operation of the mind above the simplest. It is implied in every act of judgment. Whenever we use a common noun we make use of classification or its results. Every catalogue, every index, every table of contents, the arrangement of our houses and of our streets attest the necessity we feel ourselves under for classifying objects. It is a universal process, and is common to all human

minds. It is this process of classification that constitutes science and renders possible scientific knowledge.

Classification of a series of objects is the ideal or the actual arrangement of those together that are alike and the separation of those that are unlike. It enables us to do two things: First, it enables us to retain in mind the characters of many objects at once, as well as to infer from things known, unknown correlative characteristics. It is a labor saving process. It conserves mental effort, and this economy of mental effort is perhaps the most important principle in education. It is the thing that largely constitutes the difference between the mind of great power and one of little power.

But classification does something more than this. Classification discloses to us the correlations or laws of union of property and circumstances. It is only when we make a proper classification that these laws appear. We are inclined to think that for every series of objects there is one system of classification that is best, which we call the natural system, and much energy is devoted to the discovery of that system. The so-called natural system of classification in animals and plants is a genealogical system intended to show the relationship by descent of the individuals classified. This system is not yet complete. We do not know enough about animals and plants to adjust them satisfactorily in their places. But there is no question that the arrangement of organized beings in the natural system of classification has been productive of the greatest good in the development of our scientific knowledge, and in disclosing some of the profoundest and most far-reaching truths.

But the natural system of classification is not the only one that may be used to advantage, nor the only one that is still employed in classifying animals and plants. Other systems of classification disclose other laws than those of descent. We still have, and we still need, the classification of geographical regions, of temperature zones, of life habits, of geological horizons, of physiological functions. Each of these classifications is necessary and will always be used because each discloses natural laws that constitute an essential part of scientific knowledge.

I think I do not overestimate the importance of the study of classification as an element in education. There are certain elements of dynamic thought involved in classification that are positively fundamental. Somewhere in the life of a student there must be a place in which the processes and methods of classification are consciously worked out. If this can be done in one or two subjects, the principles of classification can be applied to other subjects and be used as a tool to make further acquisitions of power in other directions.

Botany and zoölogy are the classificatory sciences *par excellence*. Here the principles of classification have been worked out with a minuteness and fullness of detail observed in no other subject. Here, if anywhere, the student must get his knowledge of those principles. In my opinion, botany and zoölogy must rest their claims for introduction into a course of study largely upon the fact that they are classificatory sciences, and any attempt to substitute some other element than classification as a basis for work in these subjects is to discard an element of greater importance for one of a less.

I am not unmindful of the fact that both subjects involve many departments in which the element of classification is not the conspicuous process. Such are the departments of physiology, histology, cytology, paleontology, embryology, ecology. Each of these may be taken as a basis of knowledge of animals and plants. My contention is that in an elementary course, it is highly injudicious to make anything but taxonomy the basis of the work. The other departments are tributary to this and should be so recognized. They are highly specialized departments, and can scarcely be studied in their full significance without some knowledge of the taxonomic relations of the forms used as types. I would make taxonomy the basis of the work and group around it the essential features of all the other departments, not by any means omit them.

Just here I should like to pause long enough to comment upon the value that exists in systematic work in botany and zoölogy. It is a kind of work that has of late fallen very much into disfavor, and very properly, too, in consequence of the great abuse to which it has been subjected. The marks that are used to dis-

criminate genera and species are apparently so trivial that they seem ludicrous. I merely wish to suggest that the variation in physiological function and life habits are usually much more pronounced than are the morphological differences that can be quantitatively stated and used to discriminate species. Even among individuals of the same species such variations of personality occur that we need to study many individuals of the same species in order to obtain an insight into the psychology of species. Also I would suggest that all the most delicate work of the embryologist, the histologist, the ecologist, everybody who contributes to the knowledge we possess of an individual of a particular species only helps us to arrive at a better understanding of the relationships that exist among the various groups of animals and plants, which is precisely the thing that the systematist attempts to do in a rough and ready way.

THE EDUCATIONAL VALUE OF PHYSICS.

BY WILBUR A. FISKE.

Instructor in Physics, Richmond (Ind.) High School.

The educational value of any subject certainly depends upon what we understand to be the purpose of education.

If, according to Plato, "It is to give to the body and to the soul all the beauty and all the perfection of which they are capable," or, according to Stewart Mill, "It includes whatever we do for ourselves and whatever is done for us by others for the express purpose of bringing us nearer to the perfection of our natures," or if, as Herbert Spencer would put it, "Education is the preparation for complete living," then physics, we maintain, will always command the respect of educators for the powers it possesses in fulfilling the requirements of these different views.

If the purpose of education is to prepare a boy or girl to make a living, then the study of physics, scientifically pursued, is not an unprofitable outlay of time. Or if it has for its aim something higher and nobler than this—the quickening of the latent intel-

lectual and even the moral powers—we still maintain it will stand out prominently among other subjects in accomplishing its ends.

While much has been said on physics, it is not by any means a wornout subject. It is of too recent development for that. Although the subject has for centuries been taught in the schools, yet, from a scientific standpoint—the only one from which we can in this day consider it—its birth dates back but a few decades.

A quarter of a century ago scientific physics had but little place in our schools. Since that time it has been placed in the front rank along with other strong subjects of the curriculum. In many cases other work has been cut down in time or wholly removed to give place to physics, the latter having been recognized as of great value from a cultural point of view, and therefore an important feature in education.

The object of physics as taught in the schools is not to place the individual in possession of a fund of knowledge in regard to facts and theories. It is of little consequence in later years that one has by experiment proved the laws of the pendulum, or that a certain fixed numerical value represents the latent heat of steam. These facts and figures will fade away as scaffolding from a building, but that which inevitably follows as the result of working these things out remains to the end the beautiful and enduring structure.

The true purpose of any subject of study, then, is not to impart facts alone, however valuable these may be, but to furnish power—a mental power that will stand by and aid one in fulfilling the important relations of life.

In the acquirement of this power, physics, we hold, is of pre-eminent value, from the fact that it affords such a wide range of culture. While there is a supreme beauty and pleasure to the lover of science in knowing the cause and effect of natural phenomena, yet the great value of this subject does not lie here, but is found in the power it possesses of developing the faculties of the mind.

If rightly pursued, physics is vigorous in the demand it makes for a strict habit of observation. It is not a superficial observation

that is demanded on the part of the subject, or fostered by a study of it, but an observation that is persistent. To become a good runner, one must run, or a good singer, one must sing. Equally so, to become a good observer, one must observe—to see things as they are, and be able to describe them in their minutest detail. Such an observation as this is fostered by a study of physics.

It is remarkable what little power the average boy or girl seems to possess in the way of observation when entering this domain of science. They seem to be utterly helpless to see, even approximately, what is before their eyes, and then describe accurately what they have seen. This, we are led to believe, is in a large measure due to a neglect of earlier scientific training.

A training of the observation cannot begin at too early an age, and there is hardly a subject more potent in the development of this faculty than easy lessons in science. Neither should this training be relaxed at any time, but should be pursued vigorously and systematically throughout the earlier school years of the child, thus preparing him to fully appreciate and grasp with firmer hold the more intricate principles and problems of the higher sciences.

The acquirement of this power of observation is greatly accelerated by means of object-lessons. Less study about things and more study of things themselves. "Object-lessons," says Spencer, "should be extended to a range of things far wider and continue to a period far later than now. They should not be limited to the contents of a house; but should include those of the field and of the hedge, the quarry and of the seashore. They should not cease with early childhood, but should be so kept up during youth as insensibly to merge into the investigations of the naturalist and the man of science."

Physics also, if rightly pursued, insists upon the closest application of thought. Uninterrupted thought on the part of the student is demanded for a perfect comprehension of the principles which the subject involves. If these demands are carefully obeyed a mental power not before possessed will surely follow.

The principles and laws of physics have been established only by men of genius, and if carefully worked out to a full under-

standing can not fail to give an increasing power in fixing the mind upon a given question, and holding it there until a definite end is reached.

This power of mental concentration is one of the most valuable acquirements of a lifetime, for mental concentration leads to clearer thinking, and clearer thinking leads to a more perfect expression of thought in words, while the expression of thought in well selected words is a certain mark of culture, and any subject of study that will aid in the smallest degree to confer this gift upon a boy or girl should receive a good share of time in any school.

A study of physics also awakens a spirit of investigation. There are exceptions to this, however, it might be said, yet I have learned from experience that a bright, active boy—and there are a few such in every school—is not content to loiter lazily along the border line of this great field of science, but he has a constant desire to push out and make short excursions alone for the purpose of investigating something that has been suggested to him by some other thing he has previously done. This may be boyish investigation, but, nevertheless, it is investigation, and shows that he has received an impetus in the right direction, which, if rightly encouraged, will lead to greater victories.

The value of all this does not lie in the fact alone that additional knowledge is gained, but the great acquirement is the power which comes by seeking these things out; by verifying principles and proving established laws.

Again, physics cultivates the imagination. By experimentation certain facts are discovered. In order to account for these facts, it is necessary in many cases to imagine a cause, which, if it existed, would readily produce such results. This leads to the establishment of a theory the apprehension of which greatly accelerates the power of imagination. It is not necessary that this theory be established by the student. Indeed, such a thing would be impossible; but, if he is alert to his task, he will actually live over again, in a great measure, the whole mental process that was evolved in leading up to this end.

Another important educational value of physics is the part it performs in the development of the power to reason and judge correctly. Each principle and law of physics is designed to cultivate and train these faculties of the mind. Each laboratory experiment worked out by the student in the verification of these principles and laws should involve a process of sound reasoning, which, if carefully and persistently followed to an end, will necessarily result in acquired power along these lines. This process of reasoning must, of course, lie within the compass of the mind dealing with it; but it must be reasoning, and not seeing only. It must insist upon that kind of mental activity that will accomplish something, and not upon that sort which gives the mind unbridled freedom.

I am convinced, from my own observation, that any other kind of laboratory work is only a waste of time, energy and money, and will certainly not result in the greatest good that is possible to be obtained from this phase of the subject.

A study of physics, as well as other branches of science, will afford an excellent moral training. It is, indeed, no panacea for human depravity, but who can possess the true scientific spirit, the spirit of unselfish, honest and thoughtful truth-seeking, and not experience a general moral uplifting?

While this scientific spirit may not be possessed in a very great measure by the beginner in physics, yet it is here that the germ which finally develops into the finished product, manifests its first signs of life. A comparative study of biography will show conclusively that immorality has not held much prominence in the ranks of scientific men, far less than among men whose lives have been devoted to literature and art. These lines of thought may possibly arouse the baser passions, but scientific truth is never impure. In many other things there is a tendency to accept, without questioning, whatever has been established, which in the end must necessarily cause an undue respect for authority. A thing is true because somebody says so, or because the rule directs that it be worked out in that manner, and the pupil, in most cases, believes it without ever asking why.

It is not so with science. The mind that has been trained by a scientific culture takes nothing for granted; in fact, is asked to take nothing for granted, but seeks to test the truth of all things. The confidence and trust in one's power, produced in this way, establishes an independence which is a most valuable element in the building of a character.

"The first condition of success in scientific pursuits," Prof. Tyndall has said, "is patient industry and an humble and conscientious acceptance of what nature reveals; an honest receptivity and a willingness to abandon all preconceived notions, however cherished, if they be found to contradict the truth."

Dr. Morton, of Stevens Institute, in answer to the question what lines of study most tend to develop intellectual honesty in the minds of educated men, has said: "Those studies which involve the explanation of the laws and facts of nature, physics, chemistry, natural history, mechanics and the like, deal with immutable facts, and the student of these has no use for the sophistries by which he might mislead himself and others."

Again, a study of physics, or any other branch of science, brings the student into closer communion with men of genius—men who have spent their lives in the intellectual advancement of mankind, and whose pulse-beats have many times been quickened by the sudden revelation of some long sought truth. A careful study of the life of Galileo, Newton, Faraday, Lavoisier, Dalton, Agassiz, Pasteur, and a score of other men of science, has often inspired within the earnest student a feeling of respect and noble emulation.

We have now spoken of the many advantages gained by a study of physics. These considerations belong to the pupils' side of the question. The methods employed to bring about the best results, to furnish the broadest culture and the best equipment for the student to fulfill the purpose of his life, is the side with which the teacher has most concern. The relation between these two—method and results obtained—is one of the vital questions, for it is certainly true that the amount and quality of the culture obtained from this branch of science, as well as any other, de-

pends in a great measure upon the methods employed in conducting the work.

I am convinced of the fact that the laboratory, when properly equipped and managed, is the great field of inspiration, even to the high-school student.

There are some, however, indeed, there may be many, who never catch this inspiration, although it may be most contagious. Yet this need not be a distressing feature, for there are many boys and girls in the schools to-day who would not even catch the measles or mumps if at first they were compelled to work out a formula for the purpose of demonstrating the progress of the disease.

The work done in the laboratory, I am further convinced, to produce the best results and to command the highest respect, should be quantitative in its nature.

It is unnecessary, in this day of laboratories and the kind of work done therein, to explain what that means. We are all familiar with the term. It is likewise unnecessary to state that every quantitative experiment is qualitative also, and that the latter precedes the former in the development of the experiment.

If we were to stop, however, with the completion of the qualitative phase, the greatest good, we maintain, that is possible to be obtained from the experiment is lost entirely to the student. In view of this it is the duty of the teacher of this subject to see that the proper kind of work is mapped out for the laboratory course, and of the assistant, or whoever may have the work in charge, to see that each pupil works his experiment in a quiet, thoughtful searching manner, making in each case a sharp distinction between what he does, the observations he makes, and the conclusions drawn from observed phenomena, or the relations existing between data obtained in the progress of the work.

The note-book, which naturally comes in at this point for consideration, is also of great educational value to the student. It compels him to put into writing the thoughts that are in his mind. It aids him to a clearer expression of thought; it trains him with increasing thoroughness in scientific composition; it

impresses more firmly upon his mind the facts he has learned in the development of the experiment; it enables him to acquire more systematic methods of doing things, and, as the note-book should never, except on rare occasions, be taken from the laboratory, it teaches him to do things now, and not wait until to-morrow or some other convenient time.

To these ends it must be insisted upon that the notes be neatly written, clear, concise and simple, containing only that which is necessary to make them complete, and finally absolutely correct, or as nearly so as the manual skill and mental caliber of the student will permit.

The classroom is the second field of operation, and one to which no little importance is attached. Although the work here is in general of a different nature, yet this is the time and place for a final rounding up of the laboratory work, for the purpose of ascertaining to what extent it has been comprehended by the pupil, and to obtain a measure of the value it has been to him.

While the laboratory, as previously stated, is the place for quantitative work, in the classroom that of a qualitative nature should prevail. An occasional quantitative experiment before a class is to be commended as a valuable thing, yet the very nature of such work requires time and a close range, and should, therefore be left to the laboratory, where it can be conducted in a much more satisfactory manner. There are always objections advanced that rigid laboratory work is unattractive to the pupil, and will cause him to acquire a dislike for the subject. That it is the phenomenal, the wonderful, the awe-inspiring that lends enchantment to him and leads him on in the work. Experience has shown conclusively that such is not always the case.

There is no reason, it seems to me, when physics is in the Junior year, when the candidate for the subject has had a year and a half of algebra, a half year of geometry, and in many cases is carrying the subject of trigonometry along with that of physics, why the subject, although largely mathematical, together with the manual work it requires, in which he always takes delight, should not be most attractive to the average student in this branch of science.

The work on prepared lessons in the classroom should be illustrated to the fullest extent by qualitative experiments. And here is where the student gets the phenomenal side of the subject. His responsbility, however, should not end with merely seeing these experiments performed, but to obtain the greatest educational value from this source as well, he should be required to make the same careful and complete record of the most important experiments, at least, in this case, as he does of those he has worked out by himself in the laboratory.

I have made some experiments along this line with my classes, and have found in every case that when required to make these records in the manner here indicated they are certain to see more, and to see it more correctly, to determine closer relations, to draw more accurate conclusions, and to describe with greater ease and accuracy at any time all that took place in the progress of the experiment. The retention of the facts and principles of the text, and the lessons obtained from the experiment, are the things to be desired, and any method that will make deeper impressions and more lasting notions, if they be correct ones, will necessarily result in the greatest educational value to the student.

ON THE TEACHING OF PLANT PHYSIOLOGY TO LARGE ELEMENTARY CLASSES.*

BY W. F. GANONG,

Professor of Botany, Smith College, Northampton, Mass

In the introduction to his collected essays, Weismann says: "The history of science proves that advance is not only due to the discovery of new facts, but also to their correct interpretation." I think it is equally true that the history of science is now showing that advance is due not only to the discovery of new facts and their correct interpretation, but also to their utilization. The old-time toast, "Here's to the latest scientific discovery; may it never do anybody any good," albeit said in humor, expresses a sentiment

*Read before the Society for Plant Morphology and Physiology, at the Second Columbia Meeting, Jan. 1, 1902.

now becoming obsolete. Today we are offering this substitute: "Here's to the latest scientific discovery; may it elevate the condition of our fellow men." Of the many lines in which this humanitarian utilization of scientific research is vigorously progressing, two are of direct concern to us; first, such activities as are conspicuously displayed by the Department of Agriculture, and, second, the introduction of science into general education. It is within the province and, I take it, is the duty, of this society to promote, in these directions, the utilization as well as the acquisition of knowledge.

That the study of plant physiology is rapidly rising in educational favor, there are many evidences. The newer elementary text books, without exception, give much, perhaps ample, attention to it—an attention, it may be noted in passing, which is often better in the spirit than the performance, for not a few physiological errors are surprisingly current. Again, the Standard College Entrance Option, formulated by a committee of this society, lays much stress upon this subject; and it is notable, as shown by the report of the committee in charge of it, that of all the criticisms of the Option which have been received, not one takes any exception to the physiology. This increasing prominence of plant physiology in education is no doubt due not only to a growing appreciation of its inherent educational merits, but also to an awakening realization of its superiority as a physiological foundation for a biological education, and of its pre-requisiteness to further accomplishment in economic and ecological investigations. That it does not advance still more rapidly is due to two obstacles, both more seeming than real. First, there are the difficulties and the expense of much of the manipulation; these, however, are being rapidly minimized, if not removed, by the many contributions to the simplification of methods and appliances now appearing. Second, there are the difficulties of teaching the subject properly to large elementary classes; this is a real difficulty, but one less formidable than it appears, as I hope the following brief observations will show.

It is agreed that, in elementary work, no more is needed than from eight to twelve good,—that is, conclusive and practicable,

—experiments upon the most fundamental subjects, photosynthesis, respiration, osmotic absorption, etc. Now, the ideal plan would be for each student to try for himself each one of these experiments. This is the logical end towards which we should work; and I have no doubt that, as appliances are simplified and improved and become purchaseable at a fair cost from supply companies, this method will gradually come to prevail in the best courses. The idea of providing a laboratory with the necessary equipment may appear formidable at a first glance, but so, many years ago, did the idea of equipping laboratories with sufficient microscopes to supply one to each student, yet this is now a matter of course in good institutions. Like the microscopes, the physiological appliances, once obtained, may be used for many years. The time has not yet come, however, for so complete a fruition of our hopes in this direction, and for the present some very much simpler plan must be adopted. We all agree that mere lecture demonstrations of the subject, though far better than no treatment of it at all, yield results greatly inferior to those obtained from that individual, personal contact with things and phenomena which can only come from the student having an actual part in the proceedings. To accomplish this with my own classes, of from forty to eighty students, I have tried two methods. The earlier was to set up the experiment carefully for the class, place it in the laboratory with full explanatory notes and diagrams, etc., and expect students individually to observe and record results as if the experiment were their own. This I have abandoned because most students did not gain a clear idea of the significance of the different features of the experiment, particularly the reasons for parts of the manipulation. The second plan has worked very much better, partly, no doubt, because it catches and holds their attention better than the former plan. With the entire class assembled, and only the bare materials for the experiment upon the table, I try first to make sure that the importance and general bearing of the problem to be studied is clearly before them; in fact, I try to make the experiment seem, as it really is, not only a logical but a necessary step in their progress. Then I set up the experiment from the very beginning, explaining the reason for each step and

for the use of each piece of apparatus, the action of each chemical and the physical principles involved. The students follow, asking what questions they wish, making full notes and sketches, etc. The completed arrangement is then placed in the laboratory, and each student makes individual records of the observable results. When the results are complete, or when the result depends upon some special test to be applied, the experiment is again brought before the class; the tests are applied and results discussed. A mimeographed synopsis of the experiment, indicating the theory of the method, and giving such statements of fact as are essential to a full grasp of the subject, is then supplied to them, and from these various sources they are expected to prepare a synoptical, illustrated exposition of the object, method, results and bearings of the experiment. This is then examined and criticised like any other part of their work. The results are not ideal, but neither are the students, though upon the whole both are pretty good.

This mention of students leads me to add a word upon this phase of the subject. A serious obstacle in the way of all such studies as are here referred to is the ignorance of most students (particularly college students) not only of the rudiments of physics and chemistry, but also of the commonest facts and phenomena of the world about them. Combined with this, is a distrust of their power to use such knowledge as they possess, and a remarkable lack of spontaneity and initiative in such work. These defects in our educational system ought not to be, and it will try the mettle of our educators to remedy them.

THE TREASURY DEPARTMENT VS. FREE IMPORTATION OF SCIENTIFIC APPARATUS BY SCHOOLS.

BY H. N. CHUTE.

It is not often that one looks for the humorous in a government circular and is rewarded. But this is an age of surprises, and perhaps not one of the least of these surprises is to find a government department with a supposedly sane man at its head perpetrating such a medley of contradictions and ab-

surdities as characterize Treasury Department Circular No. 87. This circular is ostensibly issued for the guidance of collectors of customs, and claims to be a compilation of ~~readings~~ rulings of the Treasury Department and of the courts in matters relating to the free importation of apparatus by schools. Article 638 of the Act of July 24, 1897, states that philosophical and scientific apparatus, utensils, instruments and preparations, including bottles and boxes containing the same specially imported in good faith for the use and by order of any society or institution incorporated or established solely for religious, philosophical, educational, scientific or literary purposes, or for the encouragement of the fine arts, or for the use or by order of any college, academy, school or seminary of learning in the United States, or any state or public library, and not for sale, subject to such regulations as the Secretary of the Treasury shall prescribe, are exempt from duty.

The real richness of the circular is found in the interpretation that the Treasury Department puts upon what it terms "philosophical and scientific apparatus," as shown by the following examples culled from a long and varied list. "A scale indicating $\frac{1}{20}$ milligramme, and a maximum weight of 100 grains" (about 6 grammes), and "an analytical balance sensible to the seventeen-millionth of an ounce" (about 1-2 milligramme) are declared to be scientific instruments within the meaning of the act; on the other hand, a balance indicating 1-4 milligramme and a maximum load of 100 grammes was declared *not to be a scientific instrument* within the meaning of the act when a prominent high school recently tried to pass one through the New York Custom House. This balance, evidently, did not exactly meet the specifications of a scientific instrument as prepared by the department and so the appraiser accordingly levied a duty of 45 per cent on the same. Again, "aneroid barometers, used for measuring pressure and weight of the atmosphere," are declared to be entitled to duty exemption (cir. p. 5), but "aneroids" are not (cir. p. 6). "Laboratory thermometers, unmounted" (whatever that means) are scientific instruments (cir. p. 5), but "chemical thermometers" are not (cir. p. 6). "A Siemen's wattmeter" is exempt (cir. p. 5),

but a "voltmeter and an ammeter" are not (cir. p. 6). "Barometers" are classed as scientific instruments (cir. p. 5), but "pocket barometers" are not entitled to this distinction (cir. p. 6); the circular does not fix the size of the pocket governing this classification, but leaves it to the judgment (?) of the appraiser. "Objectives" need not pay duty, but "rectilinear lenses" must (cir. p. 6); neither can common lenses of any kind be imported duty free for school use. They are not scientific instruments, according to the Treasury Department. Spy glasses are declared to be strictly scientific, including even the "99 cents for 30 days only" quality; the opera glass, however, must pay duty, unless it is large enough to aspire to the rank of marine glass, when it becomes exempt. Here, again, the determination of class is left to the imagination of the appraiser. Geissler tubes are permitted to enjoy free entry, but the influence machine so largely used to light them and give them value is held up and must pay tribute to Cæsar. "Compound microscopes, if used for examining objects invisible to the naked eye," are classed as scientific, but a microscope that is small, cheap, or such as would be used in examining objects not strictly invisible to the naked eye, as many of the details of plant structure, is not a scientific instrument. Absolute alcohol can be imported duty free, but ether and many other compounds equally serviceable in a laboratory are declared dutiable. The law distinctly says that the boxes containing apparatus are entitled to duty exemption, yet the department has ruled that the case of the compound microscope is not exempt and duty shall be collected (cir. p. 7).

It is by such absurd rulings (and many more could be cited) that the Treasury Department is defeating the clear purpose of the Act and rendering less efficient the scientific instruction in our schools. What is a scientific instrument? This question has been answered by the United States Supreme Court in the Oelschlayer case as follows: "Only such instruments can be admitted to free duty as philosophical instruments as are used for the purpose of making observations and discoveries in nature and developing and exhibiting natural forces and the condition under which they can be called into activity." This definition is cer-

tainly broad enough, and gives any school the right to import any piece of apparatus, no matter how simple or how complex, cheap or expensive, provided it is to be used in making scientific observations or exhibiting the action of natural forces. It would seem that the Treasury Department has clearly no right to interpret the law as indicated by the circular in question and by their actions as well. The science teachers of this country should vigorously protest against such interpretation and bring all possible pressure to bear through the press and Congress to the end that the law may be rationally administered and that the advancement of scientific instruction may not be handicapped by the Chinese wall of exclusion recently erected at the Custom House.

WHAT IS AN INFECTIOUS DISEASE?

BY W. H. MANWARING,
Johns Hopkins Medical School.
Formerly Professor of Physiology and Hygiene, State Normal School, Winona, Minn.

For several years I have been trying to find a simple method of demonstrating the nature of infection to secondary and grammar-school pupils. It is desirable that there be a widespread understanding of the nature of contagious diseases, in order that sanitary and hygienic actions of medical boards and boards of health may have a meaning in the mind of the public at large. I take it that the creating of this understanding is one of the most important duties of the public schools.

At first, I tried various devices, all borrowed more or less directly from the bacteriological or pathological laboratories, but with unsatisfactory results. The inoculation of a mouse with *bacillus anthracis* and the demonstration, after death, of the organism in blood of the animal by cover-slip and staining methods, did not convey to the minds of the pupils the vivid conceptions I wished. The red-and-blue pictures seen under the compound microscope had little meaning to most of them. The examination of diphtheritic membrane and of consumptive sputum were open

to the same objections; special staining methods had to be used, and that and the compound microscope forced the thing off into a land of mystery and imagination.

What I wanted was a device to bring the facts before them in a vivid and picturesque manner, without staining or culture methods or any of those processes that to the scientist are so simple, but which are so enigmatic to the untrained pupil.

One year, I tried introducing cyclops into a jar swarming with vorticellae. Before many days, some of the cyclops were covered with a squirming, jerking mass of vorticellae, easily seen by a simple lens. By a stretch of the imagination, the mass might be likened to an infection. But the device was unsatisfactory; there was not elasticity enough in it; it did not readily lend itself to the development of the subject.

I have, however, found a device that fulfills, to a quite satisfactory degree, most of the requirements. The material is abundant, every boy and girl can make his observations for himself, it lends itself readily to questions as to methods of prevention, isolation, sterilization and the like, and requires nothing in the line of media, stains or compound microscopes.

In the fall of the year, every boy and girl has seen, lying about or hanging to the ceiling or window pane, the swollen bodies of flies, dead from the fly fungus. The white dust-like spores, the bloated body, the alternate white and black bands of the abdomen, have been noticed by most of them. Then is the time I give my lesson on "The Dead Fly." A simple magnifying glass shows the fungus that killed the insect and the spores about it, and questions like: "How might the fungus have gotten on the fly in the first place?", "If you wanted to kill off all the flies in the room with the fungus, how would you go to work to do it?", "If you found a dead fly and wished to prevent the other flies from getting the disease, what would you do?" and the like, bring out all the essential facts of contagion and disinfection. When this is done, the step to the conception of bacteria, infection and prophylactic measures is simple and is taken by the pupils almost instinctively and with no forcing on my part.

I commend this device to all live teachers of elementary

physiology and hygiene, as I believe it to be the best one for the purpose now before the teaching profession.*

INTRODUCTORY METEOROLOGICAL EXPERIMENTS.

WM. H. SNYDER.

There are few schools at the present day which do not at some point in their course consider the elementary principles of meterology. Very often this work is undertaken without any previous knowledge of physics or with an indistinct remembrance of some experiments and discussions which took place in the dim past. It is therefore almost always necessary to consider the subject *de novo* and develop all the necessary conceptions. If meteorology is ever to be understood, there are a few fundamental principles which must be firmly grasped and upon which as a basis the rest of the subject must be built. I have endeavored to lay this foundation by means of the following simple experiments. These experiments cover about all the considerations necessary for elementary work and can be understood by pupils without previous scientific training.

I. Air Has Weight.—Take a large bottle and weigh it full of air and then weigh again with as much of the air exhausted as possible. The difference of the two weights, which will be appreciable on a pair of ordinary laboratory scales, will be the weight of the air removed. The volume of this removed air can be found by opening the mouth of the exhausted bottle under water and sinking the bottle as the water runs in, thus keeping the level of the water outside and inside the bottle the same. The weight of the water in grams which flows in is approximately the volume of the air removed in cubic centimeters.

II. Air Exerts Pressure.—Take a tube about eighty centimeters long, open at both ends, and over one end slip a short piece of tightly fitting rubber tubing which can be completely closed by a pinch-cock. Having closed the rubber tube, as nearly as possible at the end of the glass tube, fill the long tube with mercury and invert in a cup of mercury. If the connections are tight an ordinary mercurial barometer column will be formed, showing that some force must hold the mercury up. To the average boy or girl, however, pressure means an active

*Those interested in the fly fungus will find a short description of it in the POPULAR SCIENCE NEWS for December, 1901, and in the Literary DIGEST for Dec. 28, 1901.

force. To show that the pressure here is capable of producing motion connect the open end of the rubber tube with a glass tube about 50 cm. long, placing the free end of this in a dish of colored water. Now open the pinch-cock and the colored water will be forced up into the mercury column tube. If a little of the spectacular is necessary to revive the comatose brain cells take a thin glass flask and boil a little water in it till the flask is entirely filled with steam, then, having taken it away from the heat, quickly cork it. Place the flask upon the table and allow to cool. The steam will condense and if the flask is thin enough the air pressure will crush it in. This shows strikingly the activity of air pressure. The Magdeburg hemispheres also show well the fact that air exerts pressure.

III. Pressure Decreases with Altitude.—To show this, an aneroid or mercury barometer can be carried from the bottom to the top of a building and the readings carefully made at each place. The difference must be due to the increase of altitude.

IV. Air Expands When Heated and is Compressed When Cooled.—Bend a glass tube into an S-form and fill the U-arm about half full of mercury. Place one end of the tube through a tightly-fitting cork in a flask. Heat the flask gently and the mercury will be forced up one side of the U-tube, showing an increase in the volume of the air. Place the flask in cold water and the mercury will rise in the other arm, showing a decrease in the volume of the air.

V. Air is Compressed under Pressure.—This is best shown by the use of the Mariotte's tube.

VI. Warm Air is Lighter than Cold Air.—Take two open flasks of nearly like weight and capacity and balance, in as nearly a vertical position as possible, at the ends of a beam-balance. Bring the flame of a Bunsen burner onto the upper side of the bulb of one of the flasks so that the hot air currents that are generated will have no upward component on the flask. The heated flask will rise, showing that the heated air in the flask has less weight than the cold air.

VII. Cold Air Pushes Up Hot Air and Takes Its Place.—Take a tight chalk-box and cut a hole near each end of one side of the box. Place a lighted candle above one of the holes and tightly seal lamp chimneys around each hole. The air will now rise through the chimney in which the candle is and sink through the other. This can best be shown by holding a piece of lighted paper above the cold air chimney. If the paper has been soaked in a concentrated solution of saltpeter and then dried it will give out much smoke when burning. If a pane of glass is put in one of the vertical sides of the box the horizontal air currents can be seen passing through the box.

VIII. Air is Cooled by Adiabatic Expansion.—Take the bottle used in the first experiment and pass through the cork a chemical thermometer

and a short open glass tube. Have the lower end of the glass tube which is close to the bulb of the thermometer, bent away from it so that the air, when exhausted or allowed to enter through the tube, will not impinge upon the thermometer. Now quickly exhaust the air from the bottle, noting the action of the thermometer. It will be found that the thermometer falls when the air is exhausted and returns to its original position when the air is allowed to re-enter the bottle. This movement of the thermometer is not large but easily appreciable.

IX. Air Holds Moisture.—Take a thin nickel cup or glass beaker which has been wiped perfectly dry on the outside and put into it cold water. Soon a mist will gather on the outside of the cup. This moisture could only have come from the air which surrounds the cup. The cup itself is perfectly impervious.

X. Cold Air Holds Less Moisture Than Warm Air.—Take a liter flask and put into it just sufficient water to make a thin film on the inside of the flask when shaken around. Now warm the flask gently, never bringing its temperature near to the boiling point, until the film of water disappears from the inside and the flask appears to be perfectly dry. Having corked the flask, allow it to cool. The mist will reappear on the flask. The air, when warm, was capable of holding as invisible vapor the water which was placed in the flask.

XI. Water Evaporates at All Times.—Carefully weigh a dish of water and place it in any convenient place where there is a free access of air. After some hours weigh again. The change in weight is due to the evaporation of the water. This experiment should be tried under various conditions.

XII. Ice Evaporates Without Melting.—During a cold spell in the winter, when the thermometer remains considerably below the freezing point, carefully weigh a dish containing a number of fairly large pieces of ice. Allow the dish with the ice to remain in an exposed position, protected from the sun and all heat for a day or so, and then weigh again. The ice will be found to have lost weight, although the temperature has been constantly below the freezing point.

XIII. Moving Air Turns to the Right in the Northern Hemisphere.—This can be shown by moving a piece of chalk, kept in the same vertical plane, from the pole to the equator of a globe revolving from west to east or by moving a body impelled by the equatorial velocity from the equator towards the pole. It is somewhat difficult to illustrate the latter condition, but it can be roughly shown by keeping the hand holding the chalk always opposite a certain marked point on the equator and moving the chalk vertically.

XIV. Formation of Clouds.—On a day when the room is rather cool, heat a small amount of water in a large flask to a temperature of about 80 degrees C. Through a cork in the mouth of the flask extend

two glass tubes bent to an angle of about sixty degrees. One of these tubes should reach nearly to the top of the water in the flask and the other merely through the cork. Now blow from a bellows or from the lungs through the shorter tube. Moist air will be driven out through the longer tube and coming in contact with the cooler air of the room the temperature of the mixed air will not be sufficiently high to keep the contained moisture in the form of invisible vapor and a small cloud will be formed. This is not a condensation of steam, for the flask was kept far below the point at which steam is formed, but is a mixture of moist warm air and a colder air. This is one of the most common methods of cloud formation.

XV. Composition of the Air.—In a large, tightly corked bottle, burn by means of a deflagrating spoon a small piece of phosphorus. When the phosphorus has ceased to burn and the fumes have settled, open the mouth of the bottle under water. Water rises in the bottle to take the place of something which was removed by the burning of the phosphorus, but there still remains a gas present with which the phosphorus did not combine. This residue is colorless and transparent like the air, but unlike it neither phosphorus nor a match will burn in it. It cannot be air. Now replace the water which has entered the bottle with oxygen made in the ordinary laboratory way and see if phosphorus will burn in this mixture of the unburnable gas and oxygen in the same way that it did in air. It will be found to do so. It is fairly evident then that one of the constituents of air is oxygen and that another is the unburnable gas which may be called nitrogen. To show whether there is any other constituent, draw, by means of suction, oxygen and nitrogen through lime water and afterwards draw air through it. Neither the oxygen or the nitrogen affect the lime water while the air makes it milky. There must be some other invisible constituent in the air besides nitrogen and oxygen which may be called carbon dioxide.

PRESSURE OF LIQUIDS.

BY H. D. MINCHIN.

Instructor in Physics, Detroit Central High School.

The problem of determining the pressure of liquids due to their depth has been given much attention, but the methods hitherto adopted have, in general, been quite unsatisfactory. My experiments have been directed towards determining the amount of pressure in terms of our standard weights. The method employed is that of using a tube with a rubber diaphragm stretched

across one end. This is submerged in water at different depths and the pressure recorded for each position.

The apparatus (Fig. 1) consists of a glass cylinder for water, a thistle-tube, and an indicator. Across the bowl of the thistle-tube is fastened a rubber diaphragm, and into the tube passes a plunger with a flat disk of wood on its lower end that rests upon the diaphragm. To the upper end of the plunger is fitted a pan for the weights. To the outside of the glass cylinder is attached a scale for reading the depth of the water. A thin board is clamped across the top of the cylinder; this serves as a support

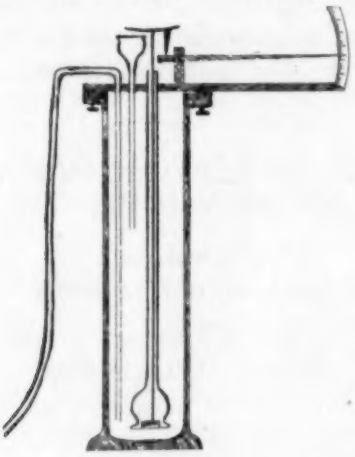


Fig. 1

for the thistle-tube, the indicator and scale, and any other parts which may be added for convenience, such as a thistle-tube for filling the cylinder with water, and a siphon for removing water when desired.

When readings are to be made the apparatus is set up, adjusted and the zero of the indicator marked. To eliminate the error due to the difference in tension of the diaphragm, the indicator is brought to the zero mark at each reading and the weight required to so adjust it is recorded.

Water is added to any depth and weights are then placed in the pan sufficient to bring the indicator to the zero mark. Then

more water is added and the adjustment is again made, and so on.

The following results show what the apparatus can do:

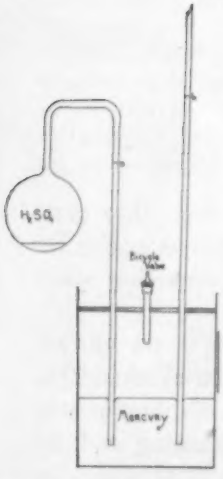
	Depth of water in cylinder.	Depth of gauge in water.	Weight added to adjust.	Pressure per cm. Depth.	Depth per 1 g. pressure.
	cm.	cm.	gram.	gram.	cm.
1	11.00	0.00	0.00	0.00	0.00
2	15.50	4.50	48.00	10.66	0.093
3	19.50	8.50	90.00	10.59	0.094
4	25.00	14.00	148.00	10.57	0.094
5	29.50	18.50	196.00	10.59	0.094
6	36.50	25.50	268.00	10.51	0.095
7	44.00	33.00	350.00	10.60	0.094

The fourth column, by the constancy of the results, indicates the relation between the depth and the pressure.

THE COEFFICIENT OF EXPANSION OF AIR AT CONSTANT VOLUME.

BY F. A. OSBORN.

Professor of Physics, Olivet College, Mich.



The accompanying figure will give all necessary details concerning the construction of the apparatus, which is simply the Boyles' Law Apparatus of Mr. N. H. Williams, of the Indianapolis High School, slightly changed in form.

The bulb has a capacity of about 250 cc. capacity. It is immersed in ice-water for 10 or 15 minutes, and then the mercury, by means of a bicycle pump is forced up to the mark *o* on the capillary stem. The readings at *o* and *b* are taken by means of a mirror-scale placed back of the tubes. The temperature should also be read at this time.

The bulb is then put into water at a temperature not much

above 30° C., and the mercury is forced up to the mark *o*. After 15 minutes the readings at *o* and *b* are taken, as well as the temperature of the water.

If we let P, P_1 and P_o represent the pressures at the low temperature t, the high temperature t_1, and at zero respectively and a the coefficient of expansion, then $P = P_o(1+at)$ and $P_1 = P_o(1+at_1)$.

$$\text{Hence } a = \frac{P_1 - P}{Pt_1 - Pt}.$$

The following results were obtained successively with the apparatus: 0.00356, 0.00357, 0.00368, 0.00366, 0.00376, 0.00365, 0.00361; mean, 0.00364, which, when corrected for expansion of glass, becomes 0.003666.

SPECIFICATIONS FOR A CHEAP AND SERVICEABLE SPECIFIC GRAVITY BALANCE.*

BY W. E. BOWERS.

Instructor in Physics, Tolt (Wash.) High School.

Section through base and standard. (*Fig.* I.)

Base (B), cast iron, 5¼" in diameter, drilled at center (C), for reception of standard; standard (S) of 5-8" steel bicycle tubing, driven into base. Both enameled.

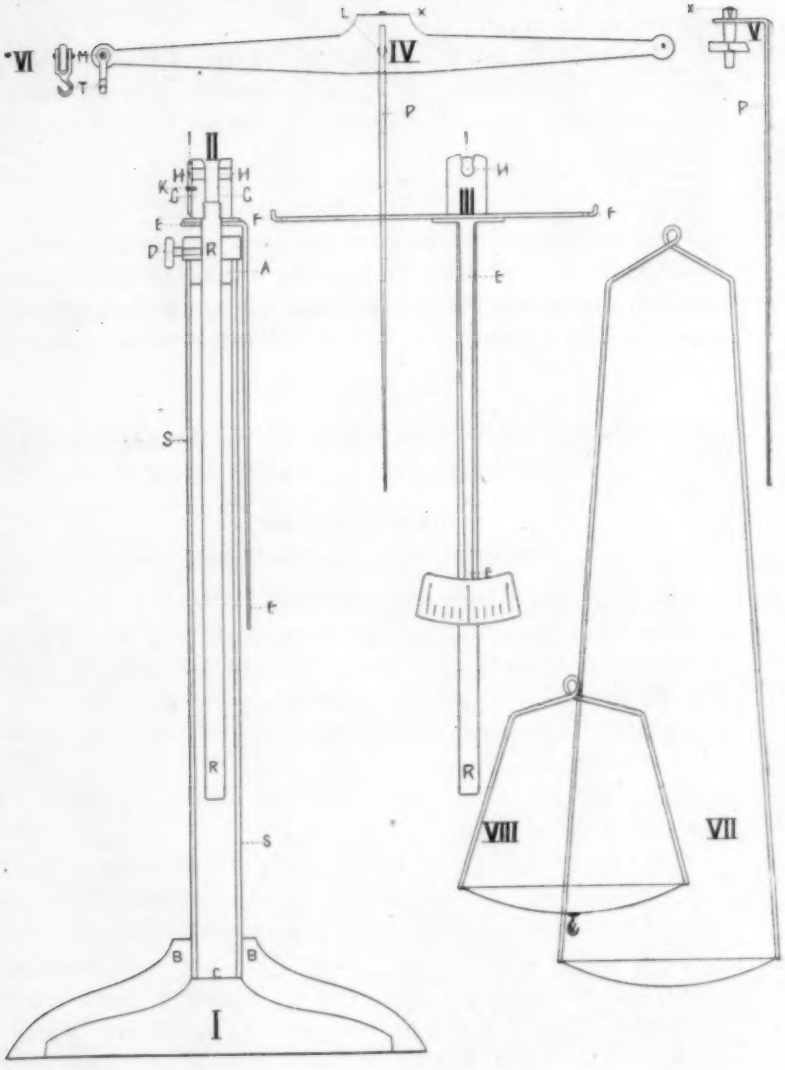
Thimble (A) of soft steel, turned and polished, with set screw (D), soldered into tube.

Side View of bearing and device for raising. (Fig. II.)

Front View of Same. (Fig. III.)

Rod (R) of 5-16" cold drawn steel, turned down to 3-16" at top, and provided with threads to move smoothly in (A). Scale (E) of sheet steel, 1-20" thick. Beam arrester (F), 1-20" steel, 6" long and ⅜" to ⅝" wide. Block (G) for main bearing, cut from soft steel, shaped with milling wheel, drill and file, and hardened; 1"x1-2x1-2", proportions as in figure. Space for pivot, (H). Plate (I) to prevent friction of beam (end of pivot rests against plate), held by screw (K).

*See this Journal, Vol. I., p. 156.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Front View of Beam. (Fig. IV.).

Section through Middle of Beam, Pivot, etc. (Fig. V.).

End View of Beam with Hook. (Fig. VI.)

Beam forged from soft steel and hardened; total length, $8\frac{1}{8}$"; greatest width, 13-16"; thickness at middle at upper edge, 3-16", at lower edge, $\frac{1}{8}$", and at the ends, $\frac{1}{8}$". Pivot (L), hardened steel, may be filed or ground sharp if it becomes dull. Pivots (M) located $4\frac{3}{4}$" from (L), measuring from knife edge to knife edge. Pointer (P) of steel wire, held by a set screw (X). Hook (T) for pan.

Right Hand Pan (Fig. VII.) of spun brass, bronzed, suspended on spring brass wire. Diameter, $3\frac{7}{8}$"; depth, $\frac{1}{2}$"; total height, 11 11-16".

Left Hand Pan (Fig. VIII.), exactly like the right hand one, except that it has a hook (V), and the total height is only $4\frac{1}{8}$".

These scales are suitable for *all* work of the laboratory where great accuracy is not required. Their maximum load is about a kilogram, although such a load would, however, somewhat lessen their sensitiveness. When new they are sensitive to a centigram. A set of six, as described above, were made in Willmar, Minn., for $18.00.

The following remarks will suggest a few of the difficulties and may perhaps be of service in avoiding them.

The block for the main bearing must be sawn and drilled perfectly true, and fit true upon the sliding rod, so that the beam will not be inclined to slide to either side.

If there is difficulty in getting the knife edges (M) at *exactly* equal distances from (L), the beam may be heated and stretched by judicious hammering, also twisted, if needs be, to bring the knife edges into exact line.

Bending the beam so as to bring the ends lower makes the balance sensitive to a smaller weight, and also more liable to swing suddenly in the annoying way that some balances have. In these balances a line drawn between the knife edges (M) and (M) passes 1-32" below the edge of (L); they are quite satisfactory in that respect.

The beam should be forged, drilled, filed until nearly balanced,

"trued up" and fitted with the pivots, which should be square bars filed to shape; the balances are then polished, balanced perfectly, fitted with the hooks and again balanced. This balancing must be done by (*a*) having the knife edges at exactly equal distances, and (*b*) by filing and polishing. Next the pans, already bronzed and made of nearly equal weight by adding solder to the shorter one, may be attached and the scales balanced again by putting on or taking off solder.

On putting away these balances, the bright parts should be wiped with a cloth moistened in sperm oil. If the physical laboratory is damp or closely connected with the chemical laboratory, it would be well to have all parts enameled, except the knife edges and bearings which can be kept oiled.

Sets of weights should be purchased of an apparatus dealer; no local workman can compete in workmanship and accuracy with the factories where the weights are stamped out or molded, without having to charge too high prices.

A SIMPLE SPECIFIC GRAVITY BOTTLE FOR GASES.

BY ARTHUR W. GRAY,

Instructor in Physics, Merced County (Cal.) High School.

A worn out incandescent electric lamp bulb makes an excellent specific gravity bottle for use with gases. The bulb, together with about half a cubic centimeter of soft wax, is counterpoised on a balance which is reliable to a centigram. Air is then admitted by cautiously filing through the side of the tip by which the lamp was sealed when exhausted at the factory. The mass of this air is now determined by restoring the equilibrium of the balance with standard masses, care being taken to replace on the balance pan any bits of glass broken off.

The air is then replaced by any desired gas, which is admitted through a small glass delivery tube inserted through the hole made by the removal of the tip. After the gas has flowed long enough to

displace all the air in the bulb, the delivery tube is removed, the opening sealed with the soft wax, and the whole reweighed to determine the mass of gas that fills the bulb.

When this process has been repeated with as many gases as desired, a small funnel is inserted in the opening and the bulb filled with water, whose mass is determined to within a gram by weighing on a coarse balance. The bulb may be emptied of water by inserting through the opening a glass tube to admit air.

In order to test the reliability of this method, I had each one of my sixteen pupils in physics determine independently the specific gravity of air referred to water, of coal gas referred to water, and of coal gas referred to air. Each of the 32 c. p. incandescent lamps used held a little more than three decigrams of air, so, with a balance not reliable beyond a centigram, no greater accuracy than three per cent could be expected. The mean of the sixteen values reported for the specific gravity of air was 0.00116. The results differing most widely from this were 0.00108 and 0.00125, while the mean variation from the mean was 0.000039, or 3.4 per cent of the mean. In judging from these figures, it should be borne in mind that the pupils were given no more assistance than absolutely necessary to make sure that they understood the method, and that in every case the first result reported to me was accepted, because it was desired to give the method as rigid a test as possible under the circumstances. If the two highest and the two lowest results be rejected, the mean remains the same as before, but the mean variation from this reduces to 2.3 per cent. The separate determinations were made on different days with the barometer ranging from 75.7 cm. to 76.6, and the temperature from 18.5° C. to 20.8° C. I neglected to have a wet-bulb thermometer read also, but I have good reason to suppose that the water vapor present in the atmosphere of the room was nearly saturated. The results obtained by the class were uniformly a little lower than that calculated for air under the above conditions of temperature, pressure and aqueous vapor. Possibly this discrepancy was due mainly to the presence of a small amount of air or other gas in the worn-out lamp.

With coal gas the agreement of results was not so good, the

mean variation from the mean being about 6.5 per cent. This seems due mainly to two causes, first, a 32 c. p. lamp holds only about two decigrams of coal gas, so that no greater accuracy than 5 per cent could be expected with a balance unreliable beyond a centigram; second, it is difficult to make sure that all the air has been driven out by the gas. Carbon dioxide or some other heavy gas ought to give better agreement among the results of the various pupils, but coal gas has the advantage of being convenient.

To secure a fair degree of accuracy the lamps used should be of thirty-two candle power or larger. A fresh bulb is, of course, necessary for each pupil, but these may be obtained for the asking from the local electric light company. Bulbs whose tips have been removed make, however, fairly good specific gravity bottles for use in the ordinary way with liquids.

THE GAMMARUS AS A SUPPLEMENTARY TYPE.

BY EDGAR A. BEDFORD,
Instructor in Biology, Lake View High School, Chicago.

The amphipod, *Gammarus,* affords an excellent form with which to supplement the laboratory work on the crayfish. It not only offers many good points for study, but it is also easy to obtain and easy to keep. A bunch of *Anacharis* brought in from a collecting trip is usually certain to furnish a good supply of material which may be kept almost indefinitely by being placed in aquaria jars. The material used here a short time ago was collected nearly a year previously. The decomposition of a portion of the *Anacharis* seems to cause the animals to thrive even better than before. I observed in September that they had been breeding during the summer, there being present large numbers of the young.

The following are some of the points to which the attention of the student may be directed:

1. Number of free somites present as compared with the number in the crayfish, and the possible bearing of this upon the position of the *Gammarus* in a classification of the crustaceans.

2. Differentiation of the locomotor appendages into three groups for walking, swimming and jumping or kicking.

3. The simple structure of the gills, being separate, finger-like processes attached to the coxal joints of the thoracic legs.

4. The eyes, the facets of which are not closely approximated, thus giving the eye the appearance of being a collection of ocelli.

5. Blood currents, which can be observed in this animal most excellently. The beating of the elongated heart and the currents of blood entering through the valvular openings in the side of the heart may be plainly seen. In the appendages good examples may be observed of currents passing towards the periphery, and of returning currents.

It may be of advantage to have pupils make tables similar to the following:

1. Jointed legs.	Characteristics of ARTHROPODA
2. White blood.	
3. Made on somite plan.	
4. Covered with chitinous shell.	
5. Breathe by gills.	Characteristics of CRUSTACEA
6. Two pairs of antennæ.	
7. Legs on thorax and abdomen.	Characteristics of MALACOSTRACA
8. Six somites in abdomen.	

A table of differences may also be made, arranging the characteristics of the two animals in parallel columns.

Since the work is done entirely with the living animal, its movements may be so rapid as to make observation difficult. These may be slowed down, however, by the use of chloretone in 0.5 per cent solution. To a small quantity of water with the *Gammarus* in a watch glass add two or three drops of the chloretone solution. If this is sufficient, the animals will begin to move more slowly in a minute or so. If they become too stupefied, add fresh water. By proper use of chloretone and water, the animals may be kept in the desired condition for some time, and they will quickly revive when placed in fresh water.

THE CAMERA IN ZOOLOGY.

BY W. H. MACCRACKEN.

Almost every one uses a camera more or less, but I think it safe to assert that very few people can be said to actually take photographs, and still fewer are those who have really done any experimentation in photography, with a definite purpose. Up to the present time there has been quite too much of the button-pressing work, and the taking of photographs has been more a matter of recreation than of practical utility.

There are several reasons for this, as I shall try to show, but just now I wish to emphasize those points which should make the camera an indispensable adjunct to any biological laboratory.

In all scientifie work it is necessary that we aid and support defective memory in some way or other, a fact which has led to the use, perhaps ultimately to the abuse, of the note-book, and which has brought laboratory sketching so much into vogue. In notes, and still more in sketches, we have to take into account the element of personality. Especially is this true when the subject studied is alive and moving, as most zoölogical matter is or should be. No two people see alike, and if two students make sketches of a somewhat complex motile organism, it amounts to a certainty that they will turn out contradictory pictures.

The camera, I need not say, is entirely impersonal. Once it is focused and adjusted properly, it makes no difference whether you or I make the exposure. In the matter of detail, our results will be precisely the same. Moreover, no one ever *drew* a picture of a moving animal for the simple reason that even a snail moves faster than it can be drawn. So that a sketch is at best a series of efforts of memory, and need not when complete resemble the animal in question, and unless made by a highly trained student is of very doubtful accuracy. Setting against this the fact that the entire picture with the exactness of detail in light and shade is possible

with the camera in 1-100 of a second or less, the advantage of the instrument appears at once.

It may be urged that the student in drawing comes to observe his subject more closely than he otherwise would.

For my part, I don't want a student of mine to observe an animal for the sake of being able to draw it in his note-book. I can scarcely imagine a more unscientific procedure. Besides, I am by no means sure that in a case where an organism moves slowly enough to admit of prolonged observation, or is stationary, a student will not observe it quite as closely in the work of accurate focusing, etc., as he would while hurriedly engaged in making a rough drawing.

For the working scientist there can scarcely be said to be any choice. The camera, properly designed and used, will win the day *every time*. It is worthy of note that in court the evidence of the photograph is accepted when the drawing is refused.

The camera is being used more and more as we appreciate the importance of studying plants and animals in relation to their environment.

Along this line, the botanists are, for obvious reasons, ahead. And many recent works owe their greatest merit to their photographic illustrations.

To my mind a great point in favor of the camera as a zoölogical instrument lies in the use that can be made of it in recording the metamorphoses so common in the life histories of many animals.

I have in mind a series of photographs which I took of *Attacus Cecropia*. These begin with the cocoon, and end with the moth with wings completely expanded. As an experiment, I mounted these pictures on a roller so that they could be presented to view in rapid succession, kinetoscope fashion, and though there were only a dozen, I was still able to demonstrate the process very nicely, and the great moth would apparently work its way out and expand (in rather a jerky fashion, to be sure), and in a few seconds instead of several hours.

In regard to the camera, there is no such thing as an "all-

round" instrument. You may be certain, if you haven't used one, that the ordinary camera sold by opticians, druggists, newsdealers and hardware men, and offered as a premium for selling soap to your neighbors, will never be of the slightest scientific use, even though it may take pretty little pictures.

Another misstatement which we often read is that it is all in the lens. This isn't so. The mechanism is extremely important, and while this or that man may boast of having taken good pictures with a lens screwed into a cigar box, I can't advise anyone to follow his plan.

The laboratory camera may be used to take landscapes and portraits, but is not to be recommended for that purpose. It must be a long bellows instrument in order to admit of varying adjustment, and should have several lenses of various focal lengths. To catch the motion of a bird's wing, it must work in 1-500 of a second, and then will fail to give a clear image in the case of a humming bird. There is no time given for micrometric focusing, Some companies are making a convertible lens that, by shifting of parts, can be made to answer all purposes.

One combination of my lens gives a focal length of 22 inches, necessitating a bellows length of nearly 3 feet, and I have often wished that I had a longer one still, for only with a lens of great focal length can an ordinary object be shown well in focus and without distortion.

Another important thing is to get the biggest, best lens that your pocket-book will allow, for those of long focus are slow, and a lens that will cut clearly to the edge of the plate with a sufficiently large aperture for instantaneous work is costly.

The camera must be constructed to work in any position. In the laboratory of the University of Buffalo, I have often found it convenient to point the lens straight downward, and again toward the ceiling. So much for the laboratory camera.

To do satisfactory work on wild animals and birds is still harder, on account of their great freedom and rapidity of motion. Very recently I contrived a piece of experimental apparatus, by means of which I have had a little success.

I took two lenses, each of 20 inch focal length, and set them so that I had a sort of double-barreled camera. One lens focused on a two-inch square piece of ground glass, and the other on the surface of a film, beside it. The two cameras being parallel, of course the picture on the ground glass was exactly like the image on the film, and by watching the glass I could tell just what sort of a picture I would get, and just when the subject was in focus. So the instant of springing the shutter was determined to a nicety.

At present scientific photography is in the act of being born. Many hard problems are as yet unsolved, and this is largely for lack of time and money for necessary research. Still work is being done, and perhaps even you and I may yet be able to put our nickel in the slot and watch the caterpillar turning to a chrysalis, the mother bird feeding her young, or a battle between rival stags, instead of a slugging match between pugilists.

A CHEAP AND EFFICIENT OXYHYDROGEN ELECTROLYTIC APPARATUS.

BY C. E. LINEBARGER.

At the prevailing price of platinum anything but a quite small electrolytic apparatus, with dilute sulphuric acid as electrolyte, is beyond the reach of most high-school laboratories. But by using sodium hydroxide as electrolyte and iron or nickel electrodes an oxyhydrogen apparatus can be readily and very cheaply made of almost any size, which will compare very favorably with those furnished by dealers. A form which I have used now for three years past is the following: A wide-mouthed bottle of 500 to 1,000 cc. capacity is fitted with a one-hole rubber stopper. From ordinary sheet iron, rectangular pieces are cut of such a size that they can just be pushed into the bottle. Stout iron wires are attached to one end of these electrodes by bending the sheet metal over on the wire and hammering it down well. Two holes are pierced with an awl through the stopper, through which the wires are thrust. An L-tube is inserted in the stopper. The bottle is

nearly filled with a solution of sodium hydroxide of about 10 per cent strength. It is very essential that this hydroxide be free from chlorin, else the iron would be attacked. Commercial sodium hydroxide, even that purified by alcohol, almost always contains enough sodium chloride as to render it worthless for the purpose under discussion. The solution may, however, be prepared by dissolving clean bits of sodium in water or dissolving sodium peroxide in water. (It is my practice to have the residues from the preparation of oxygen by action of sodium peroxide in water placed in a bottle, the sodium hydroxide thus prepared to be used in subsequent experiments.) The electrodes are then placed in the bottle, care being taken that they do not touch, and the stopper inserted tightly. The protruding wires are bent down over the cork, and can be connected with an electric current by means of double connectors. A piece of rubber tubing provided with a delivery tube is slipped over the L-Tube, and the apparatus is complete.

ELEMENTARY EXPERIMENTS IN OBSERVATIONAL ASTRONOMY.

BY GEORGE W. MYERS.

Experiment XXI.

To determine the latitude approximately.

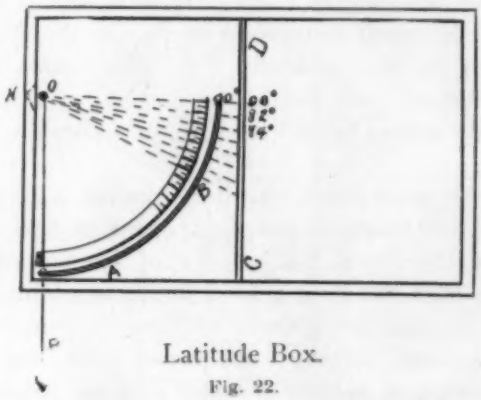
(a) Set a stake vertically on a level surface, and measure the length of the shortest shadow during the day. Also measure the height of the stake. Draw a right angle on paper, and to any convenient scale plot these measured lengths on its sides. Connect the ends of the plotted lengths and measure with a protractor the angle which is adjacent the side representing the length of the shadow. This angle will be the slant of the rays to the horizon. Take the declination of the sun for the date from the *American*

*For the convenience of those who may desire to use these experiments (there are forty-four of them) in their classes, they may be obtained in pamphlet form from "The School Science Press," Ravenswood, Chicago, at 25 cents a copy, and $2.50 a dozen.

Ephemeris, or from *The Old Farmers' Almanac* (Wm. Ware, Boston, price 10c.), add this to the measured slant and subtract the sum from 90°, and the difference will be the latitude.

(b) With the aid of the plumb-line gnomon (Fig. 21), described above (Experiment XX, (a), (2)), the length of the radius of the circle on which the shadow of the bead falls when it is nearest the bob and the height of the bead above the surface of the board may be used as the shadow length and height of stake above.

(c) Perforate the middle of one end of a pasteboard box with a needle-hole, *H*, near the bottom. Graduate into degrees a quadrant described with a point, *O*, on the bottom of the box, as near



Latitude Box.

Fig. 22.

the needle-hole as possible, as a center. A strip, *AB*, of cardboard may be bent around the arc, and pasted or glued to the bottom of the box. Or, a straight strip, *CD*, may be fastened across the box, and the graduations may be transferred to it then, as shown at 90°, 82°, etc., until *C* is reached, when they may be transferred to the lower edge of the box. (This idea is due to Professor Todd, of Amherst College.)

To use the box. Place it in position with its bottom against a vertical north and south wall, or more accurately, within the meridian plane, determined as in the last experiment, so that the plumb-line, *OP*, hangs just above the zero graduation mark. The image of the hole, *H*, cast by the sun at noon may then be seen on

AB or *CD*, and the corresponding reading be made. This gives the zenith distance of the sun directly, and with the almanac declination of the sun for the date, the latitude will be found from—

Zenith distance *minus* the declination, when the sun is south of the equinoctial (from September 22d to March 21st) and zenith distance *plus* the declination when the sun is in north declination (from March 21st to September 22d.)

Experiment XXII.

To construct a crude transit instrument.

(a) The vertical north and south wall of a building, or of two stakes set vertically in a line parallel to such a wall, may be used as a crude transit instrument by placing the eye against the north edge of the wall or north of the north stake, the observer looking southward, and noting the time when a star, or other heavenly body, passes behind the wall, or across the plane of the two stakes.

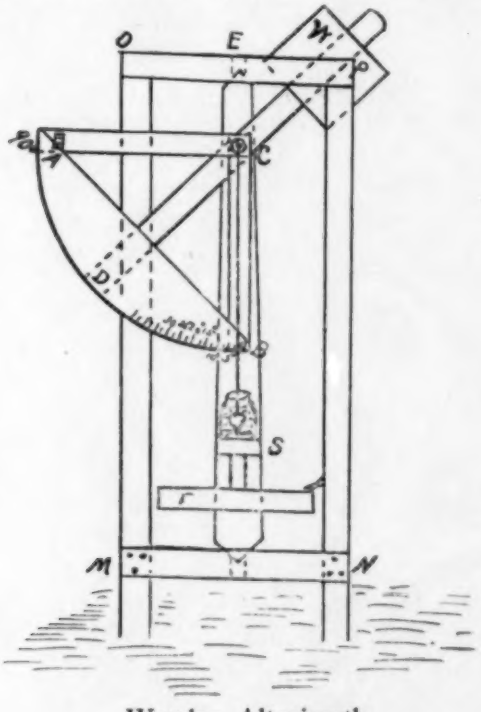
(b) A very good crude transit instrument is obtained by setting four vertical posts, or gas-pipes, in the ground as suggested by the cut of Experiment XX. (a), (1). The posts should be six to eight feet high, the long side of the rectangle inclosed by the feet of the uprights, being north and south. Suspending a continuous plumb-line, carrying a bob at both ends (the bobs may be allowed to swing in vessels of water to avoid the effects of the wind), the vertical portions of the string, or either vertical end segment with the horizontal middle segment will fix the meridian plane after it has once been fixed by star observations as suggested in Experiment XX, and the east and west top cross-pieces have been notched at *A* and *B*. North stars may be observed by placing the eye south of the south vertical end and looking northward, and south stars by standing north of the north end and looking southward.

(c) By the home-made apparatus explained on page 23 of Miss Byrd's *Laboratory Manual in Astronomy* (Ginn & Co.), a book which is highly recommended to all interested in elementary practical astronomy.

EXPERIMENT XXIII.

Construct a wooden altazimuth instrument.

With a radius of two feet describe on and cut out of a 7-8-inch board an arc, *ADB*, and graduate it to any desired accuracy. With inch oak stuff frame together a quadrant, as *ACBD* in the cut. Bolt it at C to an upright, *EF*, tapered at either end to fit



Wooden Altazimuth.
Fig. 23.

conical holes, in two pieces, *OP* and *MN*, which are nailed to two posts set firmly in the ground. Leave the bearing loose enough to allow the quadrant to move freely about *C*. The stick, *DC*, may be allowed to extend beyond *C* far enough to carry a weight, *N*, for a counterpoise; otherwise the bearing, *C*, should be adjustable.

(*To be continued.*)

Metrology*

DECADENCE OF THE VULGAR FRACTION.

BY RUFUS P. WILLIAMS.

The small boy who in answer to the question, "What is a vulgar fraction?" indignantly replied, "You mustn't expect me to know about anything vulgar," was ahead of his time. This term exists only in the memory of old inhabitants, having been long ago replaced by *common* fraction. The latter name is even more a misnomer than the former. The uncommon common fraction! It may be that few people, even teachers, are aware of the rapid change, during the last generation, in computing and representing "broken numbers."

The origin of numbers takes us back to the earliest childhood of the race, and one of the most interesting studies of primitive civilization is on the beginnings of notation, when the untutored savage set aside one for every ten fingers he counted. No one can say how old is the decimal system of notation. The Bible gives numbers in multiples of ten; for example, Genesis, 6, 15, in describing the size of the ark. Hindus, Persians, Egyptians, Greeks and Romans employed such a system. Even the tribes of American Indians in their games, played with sticks, bones and shells, kept their count in groups of ten, and students of low races cite scores of similar cases. Counting up from unity and carrying one for every ten was well nigh universal, though there have been other radices, such as 2, 5, 20, etc. But dividing or counting downward from unity was originally an entirely different matter. The first division of the unit must have been into halves, then quarters, etc., for the savage who could not understand a tenth could easily see half of anything. Indeed, the first addition also may have been with two, not ten, as the root.

Greeks, Romans and Hebrews using letters to represent their

*Communications for the Department of Metrology should be sent to Rufus P. Williams, Cambridge, Mass.)

numbers, made their developments of arithmetic under great disadvantages. The Hindu place system with zero, known to have been used in India as far back as 669 A. D., was probably introduced into Europe in the last part of the 12th or first of the 13th century, and coming by way of Arabia was called the Arabic notation. By virtue of its great superiority it rapidly spread and by the end of the 13th century was known and used by all European scholars for the expression of integral numbers. Vulgar fractions were for a long time the only ones in use, decimals being unknown. As division is more difficult than multiplication, it took 400 years more to invent and apply the decimal point, representing units divided by ten, one hundred, etc., at the right of the point. Stevinus about 1585 was "the first person who advocated and exemplified the use of decimals." Not before the beginning of the 18th century were these fractions generally understood, being at first applied as abstract rather than concrete quantities. But with decimal coinage and the metric system a great change appeared. Everything metric is decimal, and the adoption of this system crystallized decimal fractions and made their use imperative. Division came to be as important as multiplication. The processes being like those with whole numbers—except as to placing the point—scholars were not slow to recognize the advantage over the vulgar fraction of this mode of expression. About 1782 Jefferson recommended decimal coinage. In 1790 Talleyrand and the French Academy advised decimal weights and measures. Gradually this best of all systems has found its way into every land. It has got into the monetary systems of the world in which all civilized nations except three have a more or less perfect decimal coinage. The same is true of weights and measures, but with more exceptions. In countries where the system has had longest concrete application decimals are most common. In those in which the metric system is but partially in use, the old vulgar fraction holds sway, but even there we note a strong tendency to decimalize, which only means the bringing of measurements and computations into harmony with an adopted scale. Once adopt such a scale and sooner or later arithmetical processes are all dominated by it. By a process of *natural rejection* every other system is

pushed to the wall. If a decimal scale is best for addition or multiplication, it is best for subtraction or division; if best for working from right to left, it must be best from left to right; best for whole numbers, best for fractions. It is a good rule that works both ways.

Large common fractions are comparatively useless; they convey little idea, and operations upon them are most tedious. In practical life they are now generally given up. Probably the simpler common fractions, such as half and quarter, may never go wholly out of use, and there is no good reason why they should not continue to be used where necessary; but in proportion as decimals are more used, there is less call for them. The change in the United States within the last few years has been rapid, though all of it has not yet got into the arithmetics or schools. Metric tables and problems are usually relegated to the appendix of the text book, and are rarely seen by pupils, while common fractions are more studied than decimals. Schools must soon adapt their instruction to the new conditions.

Scientific workers the world over use the decimal system whether or not they employ the metric. They use it because it is best. They travel the easiest road while the populace stumbles along some other way. The teacher of physics and chemistry, as of other sciences, requires his students to measure, weigh and compute by the metric system, and problems are worked and answers expressed by the use of decimals almost exclusively.

In the accurate work of machine shops the use of decimal divisions is becoming well-nigh universal, the inch being divided into tenths, hundredths, etc., where the metric system is not employed. In surveying if the foot is used it is almost always the practice to decimalize. The vast amount of time saved by using Gunter's 100-link chain in the last 300 years cannot be estimated. The decimal notation is, with a few exceptions, wholly used in astronomical work to express both time and arc. The day, the hour, the minute and second are subdivided by ten. Even in common life the mind is moving away from vulgar fractions. Instead of saying that an article costs four-fifths more or one-half less than another, we say 80 per cent more or 50 per cent less. A score of years ago nothing was more common in the shops than

goods marked 12½, 16 2-3, 33 1-3 cents. Today the fraction is mostly abolished, 12, 17, 33 cents being substituted.

(*To be concluded.*)

Notes.

PHYSICAL.

When no Galvanometer specially fitted for the deflection of a beam of light is at hand, this crude device will sometimes be found to be serviceable, if it is desired to render the deflection due to the current visible to an audience. Attach to the end of the horizontal needle of a galvanometer a bit of straw extending vertically upward, place the galvanometer in front of the condenser of the lantern and project the straw on the screen. When the needle turns through any considerable angle, the straw is, of course, thrown out of focus, yet this will not be found to be a serious drawback in qualitative work.

G. F. S.

The Motion of the Leaves of an Electroscope is often difficult to render visible to a class. When a projecting lantern is accessible this plan may be followed: Construct an electroscope from a thin-walled flask, being sure to insulate the metal from the glass by paraffine or sealing wax. Place the instrument in front of the condenser of the lantern and focus the leaves on the screen. If the flask is thin, the glass will scarcely interfere with the sharpness of the image. A wire leading from the lecture table to the knob of the instrument completes the outfit. The lecturer can use the end of the wire near him for tests, and the class can see the resulting motions of the leaves on the screen.

G. F. S.

The Handling of Mercury.—A glass tube (quill size) drawn out to a fine jet, can be used to great advantage in handling small quantities of mercury. A supply of mercury can be drawn up pipette-fashion into the tube, and the tube then held horizontally so that the capillary attraction in the tip will prevent the liquid from running out. By inclining the tube somewhat very small amounts can be nicely delivered where wanted, as on the pan of a balance. When larger amounts are to be handled, a round bulb is blown very near the tip. Such a pipette is also very convenient in removing mercury from mercury-sealed stopcocks, etc.

Bottles may be provided with a stopper through which is passed a stout capillary tube bent at an angle of about 45 degrees, and the bottle filled with mercury. By inclining the bottle very small amounts of the mercury may be discharged quite nicely, especially if the capillary be rather fine.

The Radiation of Heat.—An experiment which cannot fail to make pupils think and which may serve as an appropriate introduction to the subject of radiant heat is the following: Hold the palms of the two hands (which must be at the same temperature) about a centimeter apart. A sensation of warmth is felt. The experiment being so simple and readily performed always arouses attention and interest, and it is easy to direct the discussion to other not so apparent cases of heat radiation.

Zeit. f. d. phys. u. chem. Unterricht, XV. 26. A. HOFLER.

Iodo-starch Paste as a Heat Indicator.—As the dark blue compound of starch and iodine becomes colorless at temperatures above about 80 degrees, use may be made of this fact to demonstrate the slight heat conductivity of water, its greater specific gravity when cold than when hot, and convection currents. Several grams of starch are rubbed up with a little cold water into a paste and then boiling water added, and the mixture boiled until it becomes "clear." A crystal or so of iodine is placed in a little water and enough powdered potassium iodide added to cause the iodine to dissolve in a short time. It is then mixed thoroughly with the starch paste. Enough of this iodo-starch paste is added to a long test tube, nearly filled with water, to impart to the latter a dark blue tint. When the *lower* part of the test tube is heated in a Bunsen flame, the *whole* liquid soon becomes colorless. If the entire length of the test tube be now put in cold water, the liquid becomes blue again, commencing at the bottom, and it can be observed that the water near the walls of the tube, which becomes cooled first, flows downwards. When the tube is again heated so as to discharge the color, and its *lower half* placed in cold water, the upper and still hot portion of the liquid remains colorless, while the lower and cooled portion turns blue. If the tube be allowed to cool and then be held in a slanting position with its middle part in a Bunsen flame, the *upper* portions of the liquid lose their color, while the lower remain unchanged.

Zeit. f. d. phys. u. chem. Unterricht, XV, 27. F. SCRIBA.

Book Reviews.

Elementary Experimental Chemistry. By W. F. WATSON, Professor of Chemistry and Biology in Furman University, S. Carolina. 13x19 cm., and 320 pages. A. S. Barnes & Co. 1901. $1.25.

This text book, which the author states "is prepared especially for the vast majority of students who take but one course," contains a considerable number of facts, usually carefully selected, deductions and theories stated in such a form that they can be easily understood and remembered. The non-metals and their commonest compounds occupy most of the book, the metals and their salts receiving scant attention.

A commendable feature is the elimination from the text proper of reference data, some of which are collected in an appendix.

Several topics that demand quantitative treatment, such as the gas laws, will hardly be clear to the beginner without considerable supplementary material in the form of explanations, examples and problems.

There are twenty full-page illustrations of the apparatus and materials used in performing the series of experiments outlined. This is certainly a step in the right direction, but it is to be regretted that the author did not see fit to label the different pieces of apparatus and also indicate their use in order to make the illustrations of some value to the "private learner" who is to use the book. The value of these experiments is diminished by the fact that the results instead of being suggested are stated directly.

Aside from the unique illustrations, the most striking and commendable feature of the book is the straight-forward and clear-cut statement of facts.

John Marshall High School, Chicago. GEORGE W. MASSLICH.

Elementary Zoology. By VERNON L. KELLOGG, M. S., Professor of Entomology, Leland Stanford, Junior University. 13x19x2.7 cm., and 492 pages. Henry Holt & Co., New York. 1901. $1.20.

In this book a number of sound pedagogical ideas have been combined. It has retained the good features of the older authors of standard text books, such as Claus, Huxley, Parker and others. It lays a solid foundation, beginning with the structure of some animal types. While the laboratory directions are kept separate throughout the book, it is one of the most successful in combining these with the text. There are three parts and an appendix.

Part I deals with the structure, function and development of animals, as an introduction to the more formal discussion of animals in systematic sequence in the second part. It might be called the European plan. The types used in the introductory part are the toad, the crayfish, the amoeba, the paramoecium and the hydra. These form the basis for a very wholesome discussion and comparison on the "differences and resemblances between the crayfish and the toad"; "modifications of function and structure to fit the animal to special conditions of life"; "vertebrate and invertebrate"; and after the amoeba and paramoecium, "the single-celled animal body," "protoplasm and the cell."

The cellular structure of the toad is followed by "the many-celled animal body," "differentiation of the cell," including division of labor. A thorough study of the structure of the hydra is used for understanding subsequent discussion on, "The simplest, many-celled animals," cell differentiation, "multiplication and development." This is followed by a special chapter on "Development of the toad" (field and laboratory exercise), and one on "The multiplication, growth and development of many-celled animals."

The second or systematic part is not general descriptive zoology, but is a practical combination of the laboratory and descriptive method. Each group is ushered in by a study of the structure of a type followed by a life-history, habits, other animals of the same kind, and ending in the general classification.

Animal ecology as such is a new departure in elementary text books on zoology. This forms the third part of the book and is carried out in good proportion with the other parts. In our estimation it is largely this part of the earlier book on "Animal Life,"* by President Jordan, and the present author that makes that book such interesting and useful reading for high schools. There are four chapters in this part on, "The Struggle for Existence, Adaptation and Species-forming"; "Social and Communal Life, Commensalism and Parasitism"; "Color and Protective Resemblances"; "The Distribution of Animals."

The three appendices give useful information on "Equipment and Notes of Pupils," "Laboratory Equipment and Methods," and "Rearing of Animals and Making Collections." It also includes the usual list of reference books. It would seem desirable to give some simple directions so that some of the more advanced students or teachers who have not had the "training in microscopical technic," might learn to prepare mounts.

Directions for finding the animals, or procuring and preparing them are given in connection with each subject under "technical notes."

Wherever the author has adopted the plan of giving the names of the parts of figures, he has carried out a commendable recent tendency of some elementary text books. Even older students tire of comparing a lot of arbitrary letters with their explanations in fine print underneath the figures, often not even alphabetically arranged. It is a drawback, especially for the young student, not to have the size of the figure-illustrations given. Students should learn to associate the picture with the actual size of the animal.

The language is generally quite unconventional, yet accurate, and so is well suited for an elementary text book. Sometimes, however, this simple presentation of an idea has led to error, as when the author says, speaking of flounders, "they have the head so twisted that the two eyes occur both together on the uppermost side." The real status of the case is more remarkable and no harder to understand. But, considering it as a first edition, the book is remarkably free from errors.

L. M.

*D. Appleton & Co.

Books Received.

Student Life and Customs. By Henry D. Sheldon. D. Appleton & Co., New York, 1901. xxii and 366 pages. $1.20.

Educational Foundations of Trade and Industry. By Fabian Ware. D. Appleton & Co., New York, 1901. xiii and 300 pages. $1.20.

Laboratory Exercises in General Chemistry. By G. W. Shaw. American Book Company, 1901. 64 pages. 50 cents.

Herbarium and Plant Description. By W. H. D. Meier. Ginn & Co., 1901. 70 cents.

Reports of Meetings.

THE NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION

Sixth Annual Meeting, Dec. 27-28, 1901.

For the third time in six years, the science teachers have met in Syracuse, through the courtesy of Syracuse University, which opened its medical college to the visitors. The success of the meeting was so gratifying that it was decided to meet in the same place in 1902.

The opening paper was by Dr. Samuel J. Saunders, of Hamilton College, on "The Value of Research Work in the Training of Science Teachers." An abstract will appear in SCHOOL SCIENCE. If space were available, a synopsis of the lively discussions elicited by this and other papers would be profitable.

The feature of the second session was the paper by Prof. N. A. Harvey, of Chicago, on "The Study of Types," an abstract of which, in three parts, is coming out in SCHOOL SCIENCE. The discussion was opened by Dr. Grant Karr, of Oswego Normal School.

The remaining hours of the afternoon, and most of the following morning, were devoted to section meetings, which are reported for this journal by the four section leaders.

There were no formal exercises in the evening. The members preferred to promote fellowship and acquaintance rather than to hear more speeches. After dining together at the Hotel Warner, they adjourned to the parlors and spent the evening socially, enjoying that leisure that many seek but few can find in a big convention.

At the brief general session following the section meetings on Sat-

urday morning, Dr. F. E. Lloyd, of Columbia University, presented "The Standard College Entrance in Botany," recently adopted by the Society for Plant Morphology and Physiology. Following this was a short symposium on the topic, "What ought the high school teacher in each science to know? What ought he to be able to do? What are his opportunities for self-improvement?" Dr. Lyman C. Newell, of Lowell, Mass., and Mr. Henry R. Linville, of New York, were the principal speakers.

At the closing session, Saturday afternoon, Prof. Irving P. Bishop, of Buffalo, read the report (of progress) of the Committee on Stimulants and Narcotics, summarizing the results of their investigation into the effects of the teaching of temperance as required by our state law. They believe that our law could be amended so as to be more acceptable to practical educators and to promise more satisfactory results. Following the report came the address of Prof. W. O. Atwater, of Wesleyan University, on "Alcohol Physiology in the Public Schools." After disclaiming any desire to have his own experiments taught in the schools while there is so much of greater importance to teach in the way of conclusions, he said:

"The amount of teaching of temperance physiology and the space given to it should be much less than is required by the legislation of a considerable number of states, including your own. The kind of teaching should be that which agrees most closely with the attested principles of physiological science; that which is both scientifically and pedagogically most reasonable."

He would have some of the time and space now devoted to alcohol physiology given to the subject of food and nutrition in general, since a large part of preventable disease is due to errors in diet.

After pointing out various mistakes in our temperance text books, he discussed the physiology of alcohol, and summed up his belief as follows: "It is, under some circumstances, a valuable nutriment, in the sense that it can yield energy to the body, but not in the sense that it can build tissue. It is, under other circumstances, a poison in the sense that it is injurious to health. When taken in large enough quantities and for long enough time it is destructive to life. It is sometimes very useful and sometimes very harmful, but the harm that comes from drinking, in many communities, vastly exceeds the good.

"While we cannot deny to alcohol a nutritive value, that value is very limited. In yielding energy to the body, it resembles sugar, starch and fat, though just how and to what extent it resembles them, experimental inquiry has not yet told us. It differs from them in that it does not require digestion, and is hence believed to be more easily and readily available to the body. It is not stored in the body for future use, like the nutrients of ordinary food materials. The quantity that may be advan-

tageously used is small. If large amounts are taken, its influence upon the nerves and brain are such as to counteract its nutritive effect, and it becomes injurious in various ways. And, finally, there are many people who begin by moderate use and are led to disastrous excess.

"Alcohol may be useful to one man and harmful to another. One may take considerable without apparent harm, while another may be injured by very little. One may use it habitually without injury, while another may not. In sickness it may be a priceless boon, but it may likewise be the cause of physical, mental and moral ruin. The boy or the man, as long as he is in good health and does not need alcohol for medicine, is, in general, better off without it."

He spoke of the repeal, by the last Connecticut legislature, of the former school physiology law, which, though less objectionable than those of some other states, including New York, was felt by nearly all the leading educators in the state to be too stringent. It was replaced by one requiring temperance instruction in a smaller number of grades and leaving the character of the text book and the instruction to the decision of the school authorities. This change was brought about by a fortunate co-operation of the teachers and temperance organizations of the state, including the state branch of the Woman's Christian Temperance Union; though it was vigorously opposed by Mrs. Hunt, of the Department of Scientific Temperance Instruction of the National W. C. T. U. The speaker believed that the example of Connecticut might well be followed in New York and other states.

In conclusion, Prof. Atwater said: "We wish to help the drunkard to reform; but is it necessary to tell him that no man can touch alcohol without danger? To build up the public sentiment upon which the reform of the future must depend, we wish our children to understand about alcohol and its terrible effects; but when we teach them in the name of science, shall we not teach them the simple facts which science attests, and which they can hereafter believe, rather than exaggerated theories, whose errors, when they learn them, will tend to undo the good we strive to do? In short, is not temperance advisable, even in the teaching of temperance doctrine?

"In the great effort to make men better, there is one thing that we must always seek, one thing we need never fear—the truth."

In the discussion, which lasted about an hour, Mrs. Hunt, who happened to be present, was allowed more time than any other speaker. She dwelt chiefly on the things that she has read about alcohol in her large library.

Mrs. Ella A. Boole, President of the New York State W. C. T. U., believed that it is "a reflection upon the teachers, that they have not presented the subject [physiological effects of alcoholics and narcotics] in such a way that it could be comprehended by the pupils." She attrib-

uted these results to the failure of normal schools and teachers' institutes "to impress the teachers that the object of this instruction is to make of the boys and girls intelligent total abstainers from liquor and tobacco."

Other members of the organization spoke, and the benches of the auditorium were well supplied with their literature. After remarks from several of the members, Prof. Bishop's report was accepted without a dissenting vote and his committee continued for another year.

The officers for 1902 are: President, Prof. William Hallock, Columbia University; Vice-President, Prof. Howard Lyon, Oneonta Normal School; Secretary-Treasurer, A. R. Warner, Auburn High School.

New members of the Council: Prof. Edward S. Babcock, Alfred University; Prof. H. J. Schmitz, Geneseo Normal School; William M. Bennett, Rochester High School.

Reported by F. W. BARROWS.

REPORT OF NATURE STUDY SECTION—STATE SCIENCE TEACHERS' ASSOCIATION.

December 27 to 28, 1902.

The program for this section was designed to bring out the opinions of those present on the training that a teacher should have in order to teach nature study. The first session was devoted to papers and discussion of these matters, and the second session to relating of personal experience by teachers actually engaged in carrying on nature-study work successfully in their schools.

The speakers were all present and the discussions were taken up with much vigor and interest. We agreed that the basis for successfully teaching nature study lies in an interest in the subject, a belief in its educational value in the broadest sense, and in a certain amount of personal experience with nature itself. That more training is desirable if added to the above essentials, was admitted by all.

Miss Hill, Miss Carss and Professor Bardwell showed how much could be done by trained nature students in the instructing of both children and teachers. But it was shown by Miss King, Miss Whittaker, Miss Mershon, Mr. Round and Mr. Drum that special science training is not absolutely necessary to carry out the spirit of true nature study.

Mr. Beach, in presenting his plan for teachers' classes, made practical suggestions, which recommended themselves to all. No doubt, many such classes will be formed during the coming year in cities. Mention was made of the Correspondence course for teachers, conducted by the Bureau of Nature Study at Cornell University. Teachers were urged to make use of every available opportunity to increase their knowledge of subject

matter, not in order that they may teach facts, but in order that they may teach their pupils how to learn from nature.

Reported by MARY ROGERS MILLER, Chairman.

NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION.

The EARTH SCIENCE SECTION met on Friday afternoon, December 27, and on the morning of Saturday, December 28.

At the first session the subject for discussion was the question of "Geography for Training Students in the Normal Schools." Discussion was opened by four twenty-minute papers, given by Professor A. W. Farnham, of the Oswego State Normal School; Professor C. Stuart Gager, of the New York Normal College, Albany; Principal C. T. McFarlane, of the Brockport Normal School; and Professor W. S. Monroe, of the State Normal School, Westfield, Mass. The first two speakers paid particular attention to the work in physical geography that should be presented to normal students, who are intending to teach in the elementary schools; the last two speakers emphasized particularly the human side of the work as it should be presented, Professor Monroe outlining at some length what, to his mind, should be included in such a course in reference to the races of man, and their conditions and characteristics as related to their environment. All speakers agreed on the necessity of more time for geography work in the normal schools of New York State, and particularly for better co-ordination of the work, so as to secure more efficient geographical training.

The second session was devoted to the discussion of the preliminary report presented by the Committee of Seven, appointed in 1900, to outline a course in Physical Geography for the Secondary Schools of New York State. Mimeographed copies of the report of the Committee and of the course suggested by the Committee were in the hands of all who attended. After a brief presentation of the main points of view held by the Committee, the discussion was led by Head Inspector C. F. Wheelock, of the Regents Office; Professor A. P. Brigham, of Colgate University; and Miss Elizabeth Meserve, of the Free Academy, Utica. Informal discussion under a five-minute rule followed, and was participated in by many of those present.

Both sessions were particularly helpful and suggestive, and great interest was shown in the problems presented for discussion. At the close of the meeting, it was voted to ask the Association to continue the Committee of Seven for one year, with the expectation that they would, at the end of that time, present a series of laboratory exercises for Physical Geography in Secondary Schools, and a course of study for Elementary Schools.

Reported by RICHARD E. DODGE, Chairman.

PHYSICS AND CHEMISTRY AT THE NEW YORK STATE SCIENCE TEACHERS' ASSOCIATION.

The section devoted to Physics and Chemistry was in charge of Mr. J. M. Jamison, Pratt Institute, Brooklyn, N. Y. Two sessions were held and each was largely attended. At the first session, held on Friday afternoon, December 27, 1901, Professor Charles B. Thwing, Syracuse University, Syracuse, N. Y., read a paper on "The Preparation and Training of the Teacher of Physics," and Dr. Lyman C. Newell, State Normal School, Lowell, Mass., read a paper on "The Preparation and Training of the Teacher of Chemistry." At the session held on Saturday morning, December 28, 1901, Mr. R. J. Kittridge, Union Classical School, Schenectady, N. Y., read a paper on "The College Entrance Preparation of Students as Viewed from the Secondary Man's Standpoint," Professor Charles M. Allen, Pratt Institute, Brooklyn, N. Y., discussed "Chemical Laboratory Notes," and Mr. Frank M. Gilley read and illustrated a paper on "How to Meet the Problem of Teaching Physics by the Laboratory Method in Secondary Schools." A general discussion by members of the section followed each paper. According to an established custom, the papers and discussions will be published in full in the Proceedings. By kind permission of the Secretary and courtesy of the speakers, we are able to present to the readers of SCHOOL SCIENCE brief abstracts of the papers.

Professor Thwing's paper was developed along the following lines:

(1) The physics teacher should endeavor to attain to as accurate and broad a mastery, both theoretical and practical, of physics itself as lies within his range of power and opportunity. This presupposes a corresponding mastery of mathematics and implies some skill in practical mechanics.

Physics is, at least in its possibilities, the most exact of the natural sciences. The phenomena studied admit of accurate measurement and are reducible to laws which may be expressed in mathematical symbols.

The physics teacher should have, or seek to acquire, therefore, the habit of accuracy of thought. This habit will show itself in speech by the employment of exact terms and by the frequent use of such qualifying words as "about" and "approximately." It shows itself, too, in habits of promptness, order and neatness, and in manipulative skill, for the difference between a successful experiment and a failure depends oftentimes upon a turn of the wrist, while the ability to give the wrist the right turn at the right moment tells of a *habit* of accuracy which it has taken years to acquire.

(2) He should gain as wide a knowledge as possible of the related

REPRINTS OF SCIENCE CLASSICS

No. 1.

THE

ANALYSIS OF AIR AND WATER

BEING SELECTIONS FROM

LAVOISIER'S ELEMENTARY TREATISE OF CHEMISTRY

TRANSLATED AND ANNOTATED

BY

C. E. LINEBARGER

DOUBLE NUMBER. TEN CENTS.

1902.

Ravenswood, Chicago, Ill.

The School Science Press.

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BIOGRAPHICAL SKETCH.

ANTOINE LAURENT LAVOISIER was born the 16th of August, 1743, in Paris. He received an excellent education, and early showed an aptitude for the study of science. When only twenty-two years of age, he was awarded a prize for having elaborated the best plan for lighting the streets of his native city, and it is related that in the preparation of this plan, he spent six weeks shut up in a darkened room, so as to render his perception of the differences in the intensities and natures of various sources of light more acute. In his twenty-eighth year he was appointed to a high official position, that of farmer general or collector of taxes, which gave him the needed wealth and leisure for carrying on his scientific researches. He occupied himself actively with the scientific questions of the time, and by his brilliant experiments overthrew the Doctrine of Phlogiston, which had reigned undisputed for more than a century.

Lavoisier is to be regarded as the originator of new ideas and conceptions, rather than the discoverer of new facts. He was the first to insist upon the rigorous application of the balance to chemical problems, and was the propounder of the Law of the Conservation of Matter.

Lavoisier perished on the guillotine the 8th of May, 1794, at the hands of the French Revolutionists, his only "crime" being that he was an aristocrat.

AN ELEMENTARY TREATISE OF CHEMISTRY.

CHAPTER III.

The analysis of the air[1] of the atmosphere; its resolution into two elastic fluids[2], the one respirable, the other non-respirable.

Our atmosphere is a mixture of all the substances capable of remaining in a gaseous state under the ordinary conditions of temperature and pressure. These fluids form a mass of very nearly homogeneous nature, extending from the surface of the earth to the highest altitudes, the density decreasing with the altitude.

We now propose to ascertain what is the number and nature of the elastic fluids composing the lower layers of the atmosphere, and to that end we shall employ experimental means. In this regard modern chemistry has made great strides in advance; the details into which I shall enter will show that the air of the atmosphere is perhaps of all the substances of this kind the one whose analysis can be carried out with the greatest accuracy and exactness. Generally speaking, there are two ways in chemistry of finding out the nature of the constituents of a body, one by composition, the other by de-

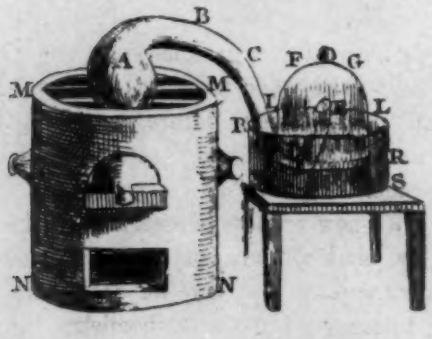
composition[3]. For example, if we mix water and alcohol and thus obtain a kind of liquor known as brandy[4], we have a right to conclude that brandy is a compound of alcohol and water; but we may arrive at the same conclusion by way of decomposition, and, speaking generally, we should in chemistry never be quite satisfied until we have combined both of these proofs.

In the analysis of the air of the atmosphere, we have the advantage of being able both to decompose and to re-compose it; and I shall limit myself to the description of the experiments which are the most conclusive in this respect. There is hardly one of them that is not original with me, either in that I was the first to perform it, or in that I repeated it according to a new point of view, *viz.*, that of the analysis of the air of the atmosphere.

I took a matrass A of about thirty-six cubic inches[5]

Fig 14

Fig 2



capacity, (Fig. 14), whose neck BCDE, was very long and had a bore of six to seven lines[6]. I bent it, as shown in Figure 2, so that it could be placed in a furnace MMNN, while the extremity E of its neck projected up into the bell jar FG, set in a mercury bath RRSS. I introduced into the matrass

four ounces[5] of very pure mercury, and then by suction through a siphon, which I placed under the bell jar FG, I caused the mercury to rise up to LL. I marked this position very carefully with a strip of gummed paper and read the barometer and thermometer.

Everything being thus in readiness, I lighted the fire in the furnace MMNN, and kept it going for twelve days, so that the mercury was always very near its boiling point.

Nothing of note occurred during the first day; the mercury, although not actually boiling, was in a state of continual evaporation; it covered the interior of the vessels with droplets, very small at first, which continually increased in size, until, when of a certain volume, they fell back to the bottom of the matrass to mingle with the rest of the mercury. The second day I commenced to see little red particles[6] swimming over the surface of the mercury, which during four or five days increased in number and volume; they then stopped increasing and remained in absolutely the same condition. At the expiration of twelve days, seeing that the calcination[7] of the mercury made no further progress, I put out the fire and let the vessels cool. The volume of the air in the matrass, in its neck and in the empty part of the bell jar, when reduced to 28 inches of mercury and 10 degrees of the thermometer, was about 50 cubic inches before the experiment. When the experiment was finished, the volume reduced to the same pressure and temperature was found to be from 42 to 43 cubic inches. There was a diminution of volume amounting to about a sixth. The red particles which had formed were carefully collected and separated as completely as possible from the mercury; their weight was found to be 45 grains[8].

I was obliged to repeat this calcination of mercury in closed vessels several times, because it is difficult in one and the same experiment to measure both the air and the red par-

ticles which had formed. It will therefore happen quite often that the results of two or more experiments will be combined in one account.

The air which remained after this operation and which had been reduced to five-sixths of its original volume was no longer respirable nor combustible, for animals introduced into it died in a short time, and a light was immediately extinguished, as if it had been plunged under water.

I put the 45 grains of the red substance, which was formed in the operation, into a very small glass retort, to which was connected an apparatus arranged to receive the liquid and aëriform products that might separate from it. After lighting the fire in the furnace, I noticed that as the red substance became heated its color deepened. As soon as the retort was red hot, the substance commenced to diminish in volume, little by little, until in a few minutes it disappeared completely. At the same time 41½ grains of mercury condensed in the small receiver, and there passed into the receiver 7 to 8 cubic inches of an elastic fluid which supported combustion and respiration much more vigorously than the air of the atmosphere.

When a portion of this air was passed into a glass tube about an inch in diameter, and a candle was introduced, it burned with blinding brilliancy. Charcoal, instead of burning quietly as in ordinary air, burst into flame, like phosphorus, and the light was so strong that the eyes could hardly stand it. This air, which Priestley, Scheele and myself[8] discovered at almost the same time, was called dephlogisticated air[9] by the former and empyreal air[10] by the latter. I at first gave it the name of *eminently respirable air*, for which was substituted later that of *vital air*. We shall take up the consideration of these names later.

A consideration of the conditions of these experiments shows that the mercury in its calcination absorbs the salubrious

and respirable part of the air, or, speaking more rigorously, the base[11] of this respirable part; that the portion of the air remaining is incapable of supporting combustion or respiration; and that the air of the atmosphere is therefore made up of two elastic fluids of a different and even opposite nature.

A proof of this important truth is that, if we re-combine the two elastic fluids thus obtained separately, that is, the 42 cubic inches of non-respirable air and the 8 cubic inches of respirable air, we can re-form an air which is in every respect similar to that of the atmosphere, and is almost as well adapted for combustion, respiration and the calcination of metals.

Although this experiment furnishes an exceedingly simple method of separating the two principal elastic fluids of the atmosphere, it does not give us an exact idea as to the proportion of these two fluids. The affinity of mercury for the respirable portion of the air, or rather its base[11], is not sufficient to overcome the obstacles opposing this combination. These obstacles are the adherence of the two fluid constituents of the air of the atmosphere and the force of affinity which unites the base of vital air with caloric[11]. Consequently when the calcination of mercury is finished, or at least carried as far as possible in a given amount of air, there still remains a little respirable air combined with the non-respirable air, and mercury is unable to effect the separation of this last portion. I shall show later that the proportion of respirable air to non-respirable air, as they are found in the air of the atmosphere, is in the ratio[12] of 27 to 73, at least in the climates which we inhabit; I shall discuss at the same time the causes of the uncertainty still existing in regard to the exactness of this proportion.

Inasmuch as the air is decomposed in the calcination of mercury with fixation[13] and combination of the base of its respirable part with the mercury, it follows from the princi-

ples which I have already exposed, that caloric and light should be set free, and there can be no doubt but that this is actually the case; but two causes prevent its being manifested in the experiment which I have just described. The first is that inasmuch as the calcination lasts several days, the evolution of heat and light is spread out over so long an interval of time that it is extremely feeble at each particular instant; the second is that inasmuch as the operation is carried out in a furnace, the heat due to the calcination is masked by that of the furnace. I might add that the respirable part of the air, or rather its base, does not, in combining with mercury, lose all the caloric that was in combination with it, but that part of it remains in the new compound; but this discussion and the proofs which I would be obliged to cite would not be in place here.

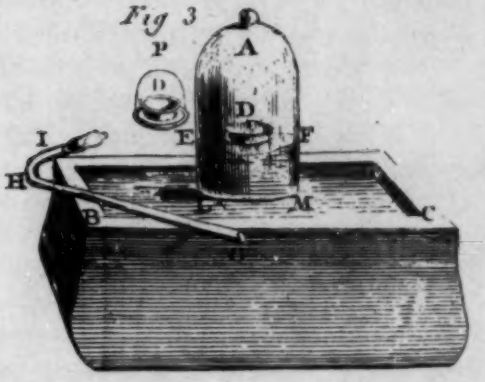
It is, however, very easy to make the evolution of heat and light manifest by effecting the decomposition of air more rapidly. Iron, which has much more affinity for the base of the respirable portion of the air than has mercury, furnishes the means thereto. One end of a fine wire BC (Fig. 17) is twisted into a spiral, and the other end B fastened to a cork fitting the bottle DEFG. A little tinder is attached to the twisted extremity of the wire. The bottle DEFG is filled with air deprived of its non-respirable portion. The tinder is ignited, and, together with the iron wire BC, promptly plunged into the bottle, which is then closed, as shown in the figure that I have just mentioned. As soon as the tinder is introduced into the vital air, it commences to burn with blinding brilliancy; it sets the iron on fire, which, while burning, throws off brilliant sparks that fall to the bottom of the bottle in rounded globules, which become black when cool, and then present a luster approaching

Fig. 17

that of metals. Iron which has been burnt in this manner is more fragile and brittle even than glass; it may be reduced readily to a powder, and is still attracted by a magnet, although less so than before its combustion.

I filled a bell jar (Fig. 3), of about six pints capacity, with

Fig 3



pure air, that is to say, with the eminently respirable portion of the air. With the aid of a very shallow vessel, I transferred this jar to a mercury bath contained in the basin BC. I then carefully dried with bibulous paper the surface of the mercury, both inside and outside the jar. Having provided myself with a small porcelain capsule D, I placed in it some thin strips of iron, twisted in a spiral form, and arranged them so that the combustion could readily spread through the entire mass. I fastened a bit of tinder to the end of one of the spirals and added a fragment of phosphorus weighing scarcely a sixth of a grain. I introduced the capsule under the jar by raising it up a little. I am not unaware that by such a procedure a small amount of common air may enter and mix with the air in the jar; but this admixture is so slight, when one is care-

ful, that it does not at all interfere with the success of the experiment.

After the capsule D is introduced into the jar, part of the air it contains is removed by suction so as to raise the level of the mercury up to EF; a siphon GHI is used for this purpose, which is slipped under the jar and which has a bit of paper twisted around the end to prevent its becoming filled with mercury. It requires some little address to raise the level of the mercury in this way by suction; if the air is drawn out by the action of the lungs alone, it is not possible to obtain but a slight elevation, as, for example, an inch or an inch and a half at the most, while by the action of the muscles of the mouth the level can be raised without difficulty six or seven inches.

When everything is in readiness, a bent piece of iron MN (Fig. 16), fashioned for this kind of an experiment, is heated to redness in a fire. It is then passed under the jar, and before it has time to cool off it is brought close to the little piece of phosphorus contained in the porcelain capsule D. The phosphorus takes fire at once and ignites the tinder, which, in turn, ignites the iron. If the spirals have been properly arranged, all the iron burns to the last atom[14], giving out a brilliant, white light, similar to that observed in certain Chinese fire-works. The great heat generated during the combustion melts the iron, which falls in round globules of different sizes to the bottom of the capsule, although some are thrown out and float on the surface of the mercury. At the commencement of the combustion there is a slight increase in the volume of the air because of the expansion caused by the heat; but a rapid decrease in volume soon succeeds this increase, and the mercury rises in the jar. When there is sufficient iron, and the air taken is very pure, nearly all of it is absorbed.

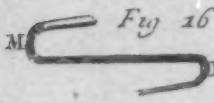


Fig 16

I should state here that it is not well to use too much iron. When the experiment has proceeded so far that most of the air is absorbed, the capsule D, floating upon the mercury, approaches so close to the top of the jar that the great heat, together with the sudden chilling due to contact with the mercury, may break the glass, and the weight of the mercury, which rapidly falls if the glass should crack, causes a large part of the liquid to flow over the sides of the trough. To avoid this and to insure the success of the experiment, not more than a *gros*[15] and a half of iron should be burnt in a jar of eight pints capacity. The jar must also be strong enough to withstand the weight of the mercury it is intended to contain.

In this experiment it is not possible to determine at one and the same time the increase in the weight of the iron and the changes which the air undergoes. If the increase in the weight of the iron and its relation to the quantity of air absorbed is to be found, the level of the mercury before and after the operation should be marked very accurately on the bell jar with a diamond. The siphon GH (Fig. 3) is covered at one end with a piece of paper to prevent its becoming filled with mercury, and, with the thumb pressed over the other end G, it is passed under the jar. By moving the thumb aside a little, air can be admitted gradually. When the mercury inside has fallen to the level of that outside, the jar is removed gently, and the globules of iron contained it it, as well as those floating on the mercury, are carefully collected and weighed. This iron has a sort of metallic luster, is very brittle and friable, and may be readily reduced to a powder under the hammer or pestle. In a successful operation, 100 grains of iron will yield 135 to 136 grains of this substance.

If this experiment be given all the attention it merits, it will be seen that the diminution in the weight of the air is exactly equal to the increase in the weight of the iron [16]. If

then 100 grains of iron are burnt and the increase in the weight of the metal is 35 grains, the diminution of the volume of the air is almost exactly 70 cubic inches, so that half a grain of air occupies one cubic inch. Later we shall show that the weight of a cubic inch of air is almost exactly half a grain.

I will call to mind again, and for the last time, that in all experiments of this kind, the volume of the air at the beginning and at the end of the experiment should always be reduced by calculation to that which it would occupy at 10 degrees of the thermometer and at a pressure of 28 inches of mercury. I shall discuss in some detail the method of making these corrections at the end of this work.

If the quality of the air remaining in the jar is to be examined into, the operations are somewhat different. After the combustion is finished and the vessels are cool, the iron and the capsule containing it are removed by thrusting the hand up through the mercury into the jar. Then potash or caustic alkali, dissolved in water, or potassium sulphide, or any other substance whose action upon the air is to be investigated, is introduced into the jar. Later I shall revert to these methods of analyzing the air and will describe the properties of these substances, which I now mention but incidentally. Finally enough water is introduced under the same bell jar to displace all of the mercury, a plate or other shallow vessel passed under it, and the whole transferred to a pneumatic trough, where any experiments can be performed on a larger scale and with more facility.

When the iron employed is very soft and pure, and the respirable portion of the air is free from any admixture of non-respirable air, the air remaining after the combustion is still just as pure as it was before the combustion; but it is rare that the iron is exempt from a small amount of carbonaceous material; steel, in particular, always contains some. It is also

extremely difficult to obtain the respirable portion of the air perfectly pure; it is nearly always mixed with a small proportion of non-respirable air, which, however, does not interfere with the result of the experiment, and is found in the same quantity at the end of the experiment as at its commencement.

I stated above that the nature of the constituent parts of the air of the atmosphere could be determined according to two methods; by way of decomposition and by way of composition. The calcination of mercury offers an example of both these methods, for, after having removed the respirable part of the air by heating it with mercury, we have restored it again so as to form an air in every respect similar to that of the atmosphere. But we can also effect such a decomposition of atmospheric air by deriving from the different kingdoms of nature the materials forming it. We shall see later that when animal substances are dissolved in nitric acid, a large quantity of an air is evolved which extinguishes flames, suffocates animals, and is similar in all respects to the non-respirable portion of atmospheric air. If to 73 parts of this elastic fluid, 27 parts of eminently respirable air, derived from mercury which has been converted into a red calx[7] by heating, are added, an elastic fluid is obtained which is perfectly similar to that of the atmosphere and exhibits all of its properties.

There are many other methods of separating the respirable part of the air from the non-respirable part; but I could not consider them here without assuming a knowledge of things that properly belong in the following chapters. Also the experiments which I have described suffice for an Elementary Treatise, for in such matters as these the choice of proofs is more important than their number.

CHAPTER IV.

Nomenclature of the different constituents of the air of the atmosphere.

In what precedes, I have been under the necessity of using circumlocution in speaking of the nature of the different substances composing our atmosphere, and I adopted provisionally the expressions, *respirable part* and *non-respirable part of the air*. The details into which I shall now enter require me to proceed more rapidly, and so, after having given some simple notions of the different substances composing atmospheric air, I shall also express them in simple words.

We have not thought it advisable to change the names that have been current and well known for a long time. We have accordingly given to the words, *water* and *ice*[17], their common signification, and we have likewise denoted by the word, *air*, the collection of elastic fluids composing our atmosphere; but we have not believed that the same respect must needs be shown to the terms proposed very recently by physicists. We have thought that we had a perfect right to reject them and to put in their place other terms less liable to lead into error, and even when we have concluded to adopt those of recent origin, we have not hesitated to modify them and attach to them notions which are more clearly defined and better circumscribed.

We have derived the new words principally from the Greek and have tried to make their etymology recall the things which they denote, and we have been especially careful not to admit, in so far as it was possible, any but short words which could easily form verbs and adjectives.

In accordance with these principles, we have retained the name *gas,* first employed by von Helmont, and have included under that head all aëriform elastic fluids except the air of the atmosphere. The word *gas* is, therefore, a generic name, denoting the extreme degree of saturation of a substance by caloric[11]; it is the expression of a particular condition of a substance. It was then necessary to specify each kind of gas, and we have succeeded in doing this by adding a second word derived from that of the base[11]. We shall accordingly call water, combined with caloric and in the condition of an aëriform fluid, aqueous gas; the compound of ether with caloric shall be ethereal gas; that of spirits of wine with caloric shall be alcoholic gas. In the same fashion we shall have muriatic acid gas, ammoniacal gas, and so forth. I will dwell more at length upon this point when the nomenclature of the different bases comes up.

We have seen that the air of the atmosphere is composed principally of two aëriform fluids of gases, one of which is respirable, supports the life of animals, the calcination[7] of metals and the burning of combustibles, while the other has absolutely opposite properties, neither supporting the respiration of animals nor combustion, etc. We have given to the base of the respirable portion of the air the name of oxygen, deriving it from the two Greek words, ὀξύς, ***acid,*** and γεννάω, *I produce,* because one of the most general properties of this base is its combining with many other substances to form acids. We shall accordingly apply the name of oxygen gas to the compound of this base with caloric. Its weight in this condition is almost exactly a half-grain[5] per cubic inch, or an ounce and a half per cubic foot, all at 10 degrees of temperature and 28 inches of mercury.

The chemical properties of the non-respirable part of the air not being as yet very well known, we had to content our-

selves with the name of its base from the property the gas has of depriving animals of their life; we have accordingly called it azote, from the ἀ privative of the Greeks and ζωὴ, *life*. The non-respirable part of the air shall therefore be called azotic gas. Its weight is one ounce[5], 2 *gros*[16], 48 grains per cubic foot, or 0.4444 grain per cubic inch.

We do not pretend to deny that this name is rather singular, but such is the lot of all new names, and it takes some time for their novelty and strangeness to wear off. We have, indeed, searched a long time for a better name, but have been unable to find it. We at first thought that we would call it the alkaligenous gas, because it has been proved by the experiments of Berthollet that this gas enters into the composition of the volatile alkali or ammonia. But, on the other hand, we have not yet the proof that it is one of the principal constituents of the other alkalies. Also, inasmuch as it enters into the composition of nitric acid, we would have just as much of a right to call it the nitrogenous principle. So we were compelled to reject every name that would convey the idea of a system, and thought that the safest way to avoid error would be to adopt the name of azote and azotic gas, which simply express a fact, or rather the property that this gas has to deprive animals which breathe it of their life.

If I should dwell more at length upon the nomenclature of the different kinds of gases, I would anticipate certain topics that are reserved for subsequent chapters. It seems to be sufficient that here be given, not the names of all the gases, but simply the method of naming them all. The merit of the nomenclature which we have adopted consists principally in this: after the simple substance is named, the names of all of its compounds are necessarily derived from this first word.

CHAPTER VIII.

The principal radical[18] *of water, and the decomposition of water by charcoal and by iron.*

Until very recent times water was considered to be a simple substance, and the ancients regarded it as an element because they were unable to decompose it, or, rather, because the decompositions of water, which are continually taking place in nature, had escaped their observation; but we shall see that water can no longer be looked upon as an element. I shall not here enter into the history of this discovery, which is very modern and which is still questioned by some. The Mémoires de l'Academie des Sciences of 1781 may be consulted for information on this point.

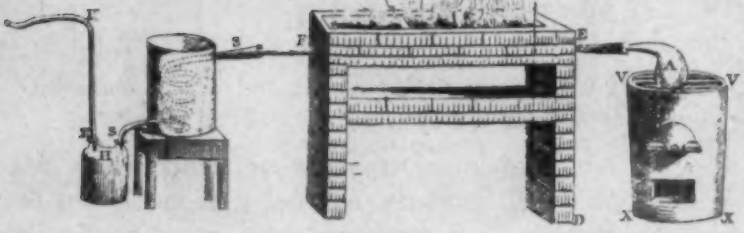
I shall content myself with giving the principal proofs of the decomposition, as well as re-composition of water; and I venture to say that anyone who will take the pains to consider them without partiality, will find them conclusive.

FIRST EXPERIMENT.

Preparation.

A glass tube EF (Fig. 11), 8 to 12 lines in diameter, is placed in a furnace so as to be inclined a little from E to F. To the higher extremity E of this tube is joined a glass retort A, which contains a known quantity of distilled water, and to its lower end F is attached a worm SS′ engaging at S in the neck of a bottle H with two tubulatures, in one of which fits a bent glass tube KK, designed to conduct the aëriform

Fig. 11



fluids or gases into an apparatus where their quantity and quality may be determined.

To insure the success of this experiment it is necessary that the tube EF be made of a difficultly fusible and well annealed glass. Outside it is covered with a clay lute, mixed with a cement made from powdered earthenware. To prevent its bending when softened by heat, it is supported in the middle by an iron bar placed across the furnace. Porcelain tubes are preferable to glass ones, but it is hard to get any that are not porous, and nearly always chinks occur in them through which air or vapors may pass.

When everything has been thus arranged, the fire is lighted in the furnace EFCD and kept up so as to heat to redness the glass tube EF without melting it. At the same time a fire is kindled in the furnace VVXX, so as to keep the water boiling in the retort A.

Effect.

As the water vaporizes in the retort A, it fills the interior of the tube EF and drives out the common air, which escapes from the tube KK; the aqueous gas is then condensed in passing through the worm SS, and the water drops into the tubulated bottle H.

If this operation be continued until all the water in the retort A is evaporated, and the vessels are well drained of their contents, a quantity of water is found in the bottle H, which is exactly equal to that which was in the retort A, and no evolution of gas has taken place. This operation then is nothing but an ordinary distillation, the result of which is absolutely the same as it would have been even though the water had not been heated to incandescence in passing through the tube EF.

SECOND EXPERIMENT.

Preparation.

The apparatus is set up just as in the preceding experiment with this sole difference that twenty-eight grains of charcoal broken up into pieces of moderate size and previously heated to incandescence for some time in a closed vessel, are placed in the tube EF.

Effect.

The water in the retort A distils just as it did in the preceding experiment; it condenses in the worm and runs drop by drop into the bottle H; but at the same time a considerable quantity of gas is evolved, which escapes by the tube KK and may be collected by means of a suitable apparatus.

At the end of the operation only a few atoms[14] of cinders are left in the tube EF; the twenty-eight grains of charcoal have totally disappeared.

The gases evolved, when examined with care, were found to weigh altogether 113.7 grains; they are of two kinds, 144 cubic inches of carbonic acid gas, weighing 100 grains, and 380 cubic inches of an extremely light gas which weighs 13.7 grains, and in contact with air, takes fire when a burning substance is

brought to it. The weight of the water in the bottle is 85.7 grains less than that originally present in the retort.

In this experiment, then, 85.7 grains of water plus 28 grains of charcoal have produced 100 grains of carbonic acid gas plus 13.7 grains of a gas burning with great ease.

But I have already shown that 100 grains of carbonic acid gas results from the union of 72 grains of oxygen and 28 grains of charcoal. The 28 grains of charcoal placed in the glass tube have therefore removed 72 grains of oxygen from the water, and 85.7 grains of water is composed of 72 grains of oxygen and 13.7 grains of an inflammable gas. We shall soon see that this gas cannot be supposed to be evolved from the charcoal, and that it must come from the water.

In the account of this experiment I have suppressed certain details which would only complicate it and obscure the ideas of the reader. The changes in the quantities thus occasioned are inconsiderable, but it seemed best to allow for them in the calculations and thus to present the results of the experiment in all their simplicity. If, however, any doubts remain as to the truth of the results from this experiment, they will soon be dissipated by other experiments which I now proceed to describe.

THIRD EXPERIMENT.

Preparation.

The apparatus is set up as in the preceding experiments with the exception of the substitution for the 28 grains of charcoal of 274 grains of very soft iron, cut into strips and rolled into spirals. The tube is heated to redness, as in the preceding experiments; a fire is lighted under the retort A, and the water is kept boiling constantly until it is completely evaporated, passed through the tube EF and condensed in the bottle H.

Effect.

No carbonic acid gas is generated in this experiment, only an inflammable gas 13 times lighter than atmospheric air. The weight of all that was obtained of it is 15 grains and its volume is about 416 cubic inches. A comparison of the quantity of water originally taken with that found in the bottle H, shows a deficit of 100 grains. On the other hand, the 274 grains of iron placed in the tube EF weigh 85 grains more than when they were introduced, and their volume is considerably increased. This iron is but feebly attracted by a magnet, dissolves in acids without effervescence, and, in a word, is the black oxide of iron, precisely the same as that obtained by burning iron in oxygen.

Reflections.

The result of this experiment shows that the iron has been oxidized by the water—an oxidation exactly like that which takes place in the air when iron is heated. One hundred grains of water have been decomposed; 85 grains of oxygen have united with the iron to form the black oxide of iron, and 15 grains of a peculiar, inflammable gas have been evolved. Water is therefore composed of oxygen and of the base[11] of an inflammable gas in the proportions of 85 to 15.

Water, therefore, besides the oxygen which is one of its principles, as well as that of many other substances, also contains another principle which is peculiar to it, which is its constitutive radical[12] and to which we find ourselves forced to give a name. None has seemed so appropriate to us as hydrogen, that is to say, the generating principal of water, from ὕδωρ, *water* and γεννάω, *I generate*. We shall give the name of hydrogen gas to the compound of this principle and caloric, and the word *hydrogen*, standing alone, shall designate the base of the same

gas, the radical of water.* Here, then, is a new, combustible substance, that is to say, a substance which has enough affinity for oxygen to remove caloric from it and to decompose water. This substance has so great an affinity for caloric that, unless it is in combination, it is always in the gaseous state under the ordinary conditions of pressure and temperature. As a gas it is about 13 times lighter than the air of the atmosphere; it is not at all soluble in water, and it does not support the respiration of animals.

The property of taking fire and burning being for this gas as for all other combustibles, nothing but the property of decomposing the air and separating oxygen from caloric, it is readily seen why it cannot burn except in contact with air or oxygen. Thus, when a bottle is filled with this gas and it is ignited, it burns gently at the mouth of the bottle and the flame gradually passes into the bottle as the external air enters; but the combustion is slow and takes place only at the surface separating the two airs or gases. A different behavior is observed, however, when the two airs are mixed before they are ignited. If, for example, one volume of oxygen be mixed with two volumes of hydrogen in a narrow-mouthed bottle and a burning substance, such as a lighted candle or piece of paper, be brought to the mouth of the bottle, the combustion of the gas takes place instantaneously with a loud explosion. This experiment should always be carried out in a very strong bottle of green glass not holding over a pint, which should be well wrapped up in a cloth. Otherwise there is danger of accident from the bursting of the bottle, the fragments of which may be projected to a considerable distance.

The name of *hydrogen* has been criticized even with some bitterness on the ground that it may mean produced from water as well as producer of water. But what does that matter, if the expression is equally appropriate in both senses? The experiments described prove that the decomposition of water gives rise to hydrogen, and especially that hydrogen generates water in combining with oxygen. It is just as well to say that water produces hydrogen as that hydrogen produces water.

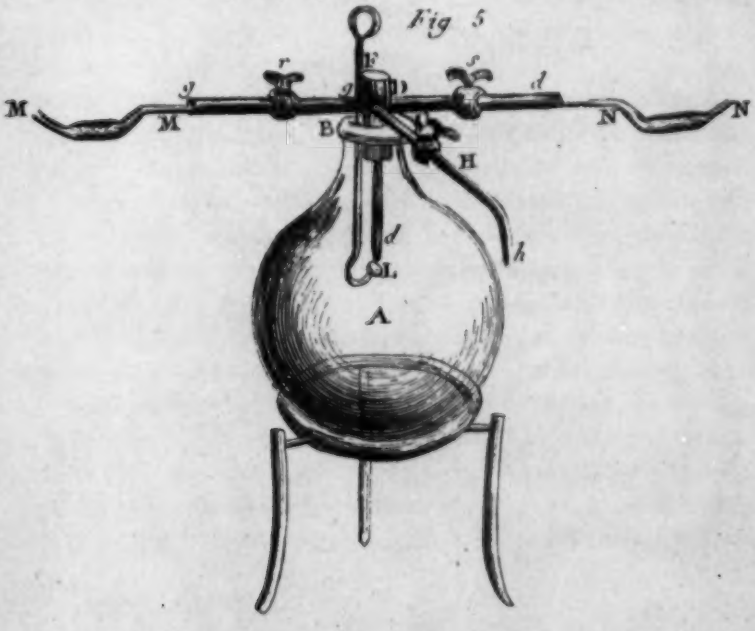
If all that I have just set forth about the decomposition of water is exact and true, if this substance is really composed, as I have endeavored to prove, of a peculiar principle, hydrogen, combined with oxygen, then it ought to follow that by re-combining these two principles, water should be re-formed, a conclusion quite in accordance with fact, as will be shown in the following experiment.

FOURTH EXPERIMENT.

Preparation.

A round bottomed glass flask A (Fig. 5) of about 30 pints capacity, has cemented over its wide mouth a copper cover BC pierced with four holes in which terminate four tubes. The first H*h* of these tubes is arranged so that it can be connected at *h* with an air pump by means of which a vacuum can be

Fig 5



created inside the flask. A second tube *gg* communicates at MM with a reservoir of oxygen gas and is so constructed that the gas can be conducted into the flask. A third tube *d*D communicates at *d*NN with a reservoir of hydrogen gas; the inner extremity of this tube has a very small opening hardly large enough for a very fine needle to enter. The hydrogen escapes by this fine opening, and to impart to it a sufficient velocity, it is subjected to a pressure of from one to two inches of water. Finally, the cover BC is pierced with a fourth hole in which is cemented a glass tube through which passes a metal wire GL at the extremity L of which is fastened a little ball so adjusted that an electric spark can be made to pass from L to *d* and thus ignite the hydrogen gas, as we shall soon see. The metallic wire GL moves easily up and down in the glass tube so that the ball may be separated from the extremity *d*. All three tubes, *d*, D*d*, *gg*, H*h* are each provided with a stopcock.

In order to be certain that the hydrogen gas and the oxygen gas are quite dry when they arrive at the tubes which conduct them into the flask A, they are made to pass through the tubes MM, NN, of about an inch in diameter, which are filled with some deliquescent salt such as the acetate of potash, the muriate or nitrate of lime. *Consult* the second part of this Work for the composition of these salts. They should be in the form of a coarse powder so that they will not run together and clog up the tubes.

A sufficient supply of well-purified oxygen should have been provided for, and in order to be sure that it does not contain any carbonic acid, it should be left for some time over a strong solution of caustic potash.

With like care twice as much hydrogen gas is prepared. The surest way to get it without any admixture is to prepare it by the decomposition of water by very ductile and pure iron.

When the two gases are ready the air pump is connected to the tube H*h* and a vacuum made in the large flask A. One or the other of the two gases is then conducted into it, but preferably the oxygen gas by the tube *gg*; then by a suitable adjustment of the pressure, hydrogen gas is made to enter by the tube *d*D*d*, of which the extremity *d* terminates in a point. Finally this gas is lighted with the aid of an electric spark. By passing into the flask each of the gases or airs, the combustion may be kept up for a very long time. I have given in another place a description of the apparatus which I have employed for this experiment, and I have explained in what manner the volumes of the gases consumed could be measured with vigorous exactness. *Consult* the third part of this Work.

Effect.

As the combustion proceeds, water is deposited upon the inside walls of the flask or matrass; the quantity of this water increases little by little; it runs together in large drops which collect in the bottom of the flask.

By weighing the matrass before and after the operation, it is easy to ascertain the amount of water collected. This experiment affords us then a double verification; the weights of the gases employed, and the weight of the water formed. In an experiment of this kind M. Meusnier and I found that 85 parts by weight of oxygen and 15 parts of hydrogen were required to form 100 parts of water. This determination, which has not yet been published, was performed in the presence of a large committee of the Academy; we gave it the most careful attention and we believe it to be exact to within a two-hundredth[20].

Thus, operating either by way of decomposition or of recomposition, we have a right to regard the result as constant, and as well proved as anything can be in chemistry or physics,

viz.: that water is not a simple substance; that it is composed of two principles—oxygen and hydrogen—and that these two principles have such an affinity for caloric that they cannot exist free except as gases under the conditions of temperature and pressure we live in.

This phenomenon of the decomposition and re-composition of water is taking place continually right under our eyes. As we shall soon see, the phenomena of vinous fermentation, of putrefaction and even of vegetation is, to a certain degree, due to this decomposition, and it seems extraordinary that this point has until now escaped the attention of physicists and chemists. We may perhaps draw the conclusion that in matters of science, as well as of morals, it is hard to overcome the prejudices which have been imbibed and to follow a path differing from the one we have been accustomed to travel.

NOTES.

This translation is made from the second edition of Lavoisier's *Traité Elémentaire de Chimie*, dated 1793. It is as literal as possible and but few liberties are taken with the text.

The selections are such as will give a good idea of some of the principal achievements of Lavoisier in chemistry. Lavoisier's own account of the first analysis of atmospheric air, which is given in a condensed form in many texts on chemistry, cannot fail to impress and interest the reader. The chapter on nomenclature gives a notion of the fundamental principles of naming things, which should be known by everyone, and the account of the analysis of water is admirable in its experimental plan, its strictness of logic and conclusiveness of results. It is believed that the beginner in chemistry will gain much benefit from the study of these selections, so different in style and treatment from the usual run of the text books of today.

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(1). What are now called gases were formerly called "airs." All gases were supposed to be but modifications of atmospheric air, or to be atmospheric air mixed with various vapors or exhalations. It was customary to distinguish different kinds of "airs" by some adjective, as "fixed air" (carbon dioxide), "vital air" (oxygen), "atmospheric air," etc.

(2). "Elastic fluid" is synonymous with gas or vapor.

(3). Or, as we now say, synthesis and analysis.

(4). We would not say today that brandy is a chemical compound, for there is no definiteness in the proportions of the alcohol, water, etc., composing it. The law of definite proportions was not enunciated until some years after Lavoisier's death.

(5). The weights and measures of the old French system, which are used in this reprint, are given below, with their metric equivalents and translation into English:

1 ligne (line) equals 2.2558 millimeters.
1 pouce (inch) equals 12 lignes equals 27.0696 millimeters.
1 pied (foot) equals 12 pouces equals 32.4835 centimeters.
1 pinte (pint) equals 931 cubic centimeters.
1 grain (grain) equals 0.0532 gram.
1 gros (gros) equals 72 grains equals 3.8304 grams.
1 once (ounce) equals 30.6432 grams.

(6). Mercuric oxide, also called red precipitate, a compound of mercury and oxygen.

(7). The heating of a metal in the air, so as to convert it into its oxide, was known as calcination before the discovery of oxygen. An oxide was then called a calx.

(8). Lavoisier here seems to claim to have independently discovered oxygen. This claim, however, can hardly be substantiated. Lavoisier's part in the early history of oxygen consisted in a careful study of its properties and relationships.

(9). "Dephlogisticated air" signifies the gas from which all combustibility has been removed; that is, the gas which does not itself burn, but supports the combustion of certain other substances. Priestley, with the other adherents of the "phlogiston theory," regarded an oxidation as due to a loss of phlogiston.

(10). "Empyreal air" means the gas containing fire; Scheele gave it this name, because much heat and light are given out when it combines with combustible substances.

(11). Lavoisier, in common with the other men of science of his time, considered heat and light to be imponderable (without weight) fluids of great elasticity, and capable of dissolving a large number of substances and of entering into combination with them. Every aeriform fluid, every kind of air or gas was supposed to result from the combination of a substance, either liquid or solid, with this caloric or principle of fire and light. Oxygen was thought to be a gaseous compound of caloric and another substance called its base; when oxygen gas comes in contact with another substance, for which it has a greater affinity, it leaves the caloric and unites with the substance. In combustion, for example, the substance which burns takes its base from the air, and the caloric escapes as heat or light.

The following extracts from the first chapter of Lavoisier's Chemistry will show how the notion of caloric was acquired:

"It is a constant and general phenomenon of nature that when a body, solid or liquid, is heated, it increases in all three dimensions. * * * If a body, which has been heated, and thus had its molecules separated more or less, be allowed to cool, these same molecules approach one another in exactly the same proportion as before; and if the body be brought back to its original temperature, it assumes the same volume it at first had. * * *

Bodies are solid, liquid, or in the elastic or aeriform state, according to the relationship existing between the attractive force of their molecules and the repulsive force of heat; or, what amounts to the same thing, according to the degree of heat to which they have been subjected.

It is difficult to consider these phenomena without admitting that they are due to the effect of a material substance, a very subtile fluid which insinuates itself between the molecules of all bodies and forces them apart; and even if the existence of this fluid be purely hypothetical, it will be seen that it explains in a very happy manner the phenomena of nature.

This substance, whatever it is, being the cause of heat, or, in other terms, the sensation which we call heat, that is the effect of the accumulation of this substance, cannot rigorously be called by the name of heat, since the same term cannot express both cause and effect at once. * * * In our work of reforming the language of chemistry, Messrs. de Morveau,

Berthollet, de Fourcroy and myself have thought it best to banish such periphrases as lengthen out speech, render it less precise and clear, and often do not even convey the idea meant. We have consequently denoted the cause of heat, the very elastic fluid which produces it, by the name of caloric. Besides fulfilling our object in the system which we have adopted, this expression has the additional advantage of adaptability to all sorts of opinions; because, speaking rigorously, we are not even obliged to suppose that caloric is a material substance. It suffices to regard it as that which causes the separation of the molecules of matter, and its effects can accordingly be considered in an abstract and mathematical manner."

(12). The ratio now adopted is 20.96 parts by volume of oxygen to 79.04 parts of other gases, mostly nitrogen, with very small proportions of argon, carbon dioxide, etc.

(13). "Fixation" denotes the combination of a gas with a solid to form a solid. Thus, carbon dioxide was called fixed air, because it combines with lime (in lime water) to form precipitated chalk.

(14). The word atom is used by Lavoisier as denoting the smallest part of a substance, either compound or elementary, and the word molecule as synonymous with a small bit or particle.

(15). As there is no English equivalent for the French word, gros, this has to be retained in the translation.

(16). We have here a clear application of the Law of Conservation of Matter, or, as it is better called, the Law of Persistence of Mass.

(17). It is noteworthy that the French language does not contain a single word for "steam," the phrase "vapor of water" (vapeur d'eau) being used.

(18). By radical is meant what we now call element. The word element being used by Lavoisier's contemporaries in the ancient fashion as applying to earth, air, water and fire, Lavoisier used radical instead. Today, when the ancient hypothesis is no longer valid, element is used for this case, and a radical is now defined to be a collection of elements acting much like an element in its various reactions.

(19). "Constitutive radical" means the component which imparts to a compound its peculiar properties. Thus, water contains hydrogen and oxygen; the latter element, being found in many other compounds, is not so important (according to Lavoisier) in giving to water its peculiar properties as is hydrogen.

(20). Lavoisier overestimates the accuracy of his results. The percentage composition of water is now taken to be 88.81 per cent of oxygen and 11.19 per cent of hydrogen.

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THE laboratory method of science teaching, at first applied to supplement the text book, has proved so valuable that the text-book work has in a measure become subordinate to the laboratory work. In the laboratory the student comes in direct contact with the facts of science, and uses his text book mainly to supplement and correlate what he has learned in the laboratory. The text book, however, too often proves inadequate. From his experience in getting knowledge at first hand in the laboratory, the student comes to feel a desire to get his knowledge of matters which from lack of time and facilities he cannot study by laboratory methods, also at first hand; he wants to consult the original sources of the knowledge of the facts given in the text. The value of "supplementary reading," as it is called, is universally recognized in the study of history and literature. It gives the student a breadth and power impossible otherwise. And so it would be in the study of science, if the original sources of information were readily accessible.

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sciences, especially chemistry, and seek to find the salient points of contact of the other sciences with physics.

(3) He should be a man among men, touching men at many points, helping and uplifting always, a man whose life embodies that strict conformity to the laws of being which his chosen science so perfectly exemplifies.

The following is a summary of Dr. Newell's paper:

(1) Teachers of chemistry need a broader, more uniform and more accurate knowledge of the fundamental facts and principles of chemistry. This is especially true at the present time because (*a*) the training in general chemistry received in many colleges is not suited for teaching in secondary schools, and (*b*) the teacher is apt to lose sight of the foundations in the multitude of facts which have been discovered in the last ten years. A convenient way to acquire knowledge of fundamentals is by reading a large text book.

(2) In order to teach chemistry a knowledge of other sciences is necessary. Interest in other sciences should be stimulated by reading scientific journals and attending meetings of scientific associations.

(3) The vital object of science teaching is to create and foster a scientific attitude of mind. No teacher can create and foster such scientific spirit, if he himself does not possess it. One of the best ways to acquire it is by doing original work. If such work is impossible, then the teacher should do some work having in it the element of originality, such as the simplification of apparatus or the improvement of some experiment. All teachers should write in order to acquire exactness of expression.

(4) The most important phase of teaching chemistry at the present time is the supervision of laboratory work. Failures in teaching are often traceable to a partial grasp of the psychology of laboratory work. In order to prevent shirking, such work must be carefully prepared and judiciously supervised, and must be searching enough to command respect, but not so difficult as to discourage. It must be followed up by questions. If the laboratory work is to relieve mental fatigue, the working period must not be too long or too short; opportunity must be given the pupils—especially girls—to sit down, the laboratory directions must not be too brief, long, or vague. The laboratory must not be left to run itself, nor should the pupil be given unlimited freedom. He should always be guided, but never told facts he can observe himself.

Pupils should be led from curiosity to interest, and by every possible device onward into the realm of voluntary attention. Quantitative work is best suited to teach voluntary attention.

Laboratory work should be so supervised that the pupil's mind can travel without needless inhibitions, i. e., interruptions, from the object of an experiment, through the manipulation, to the conclusion. Otherwise there will be loss of time and waste of mental energy.

(5) The teacher may learn these psychological principles by studying himself and his pupils. The teacher himself must pass through the gates of curiosity and interest into the temple of voluntary attention before he can lead others to the same spot.

Reported by LYMAN C. NEWELL.

QUESTIONS FOR DISCUSSION.

Teachers are invited to send in questions for discussion, as well as answers to the questions of others. Those of sufficient merit and interest will be published.

33. In one of the newer elementary text books in botany a statement is made that would lead one to believe that yeast can act on starch. On the other hand text books commonly give the impression that yeast can act only on sugar. Will someone please give the literature that will answer these questions? Is the ferment that changes the starch into some kind of sugar in the seed or flour, or does the yeast produce it?

Yeast does not act directly upon starch. Starch is readily hydrolyzed by the enzyme, diastase, which is produced by almost all plants. Diastase is present in all cells where starch is digested, and this must be done before it can be transferred from one point to another. The diastase may originate in the same cell as the starch grain, or it may diffuse in from adjacent cells. It breaks starch up into maltose and dextrine. The maltose is usually further decomposed into two parts of glucose, which may then be hydrolyzed by yeast. Yeast decomposes glucose and some other hexose sugars by excreting an enzyme, the *zymase* recently discovered by Buchner. On cane sugar it acts first by means of the enzyme, invertase, which breaks it up into glucose and fructose. These are then broken up by zymase into ethyl alcohol, carbon dioxide and other substances. (See Green's "The Soluble Ferments and Fermentation").

University of Chicago. C. R. BARNES.

34. Where can one obtain the sticks of Japanese incense for showing the path of rays of light mentioned in Dr. Porter's experiment in "Science," Oct. 11, 1901? It would also be useful for demonstrating currents in a room, in the study of hygiene.

The incense asked for may be obtained from any dealer in Japanese goods. The incense coiled in a spiral is probably better than the straight form. It is kept in Boston by Bunkio Matsuki and by Yamanaka & Co., both of whom are in Boylston street.

Physiological Laboratory, Harvard Medical School. W. T. PORTER.

35. Has anyone else observed anything like the following: One of our students brought in a piece of a weed stem on which were six or seven little paddles of ice, the fluted stem of the weed being the shafts or axis of the little paddle wheel thus formed. The plates of ice were about ⅛ of an inch thick, ⅜ wide and 1½ inches long. An explanation will be welcome

See Lester F. Ward on "Frost Freaks of the Dittany," in Botanical Gazette, XVIII, 183-186, Pl. 19, 1893; and George F. Atkinson on "Frost Freaks of Herbaceous Plants," *ibid*, XIX, 40-42, 1894.

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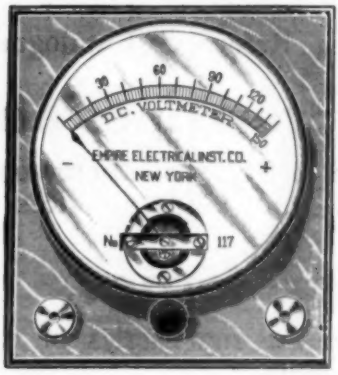

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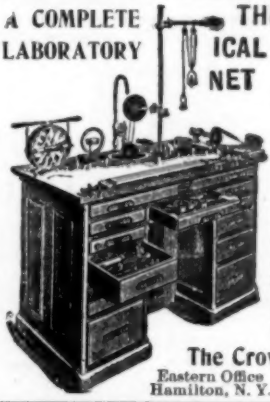

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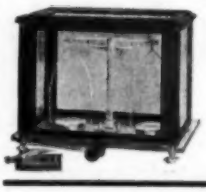

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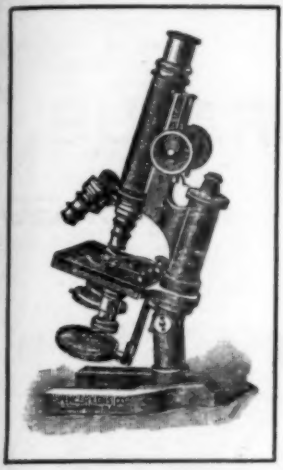

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